

THE WESTERN CANADA SERIES

HIGH SCHOOL BIOLOGY

BAILEY & COLEMAN

WITH AN ADDITIONAL CHAPTER BY  
G. V. VAN TAUSK



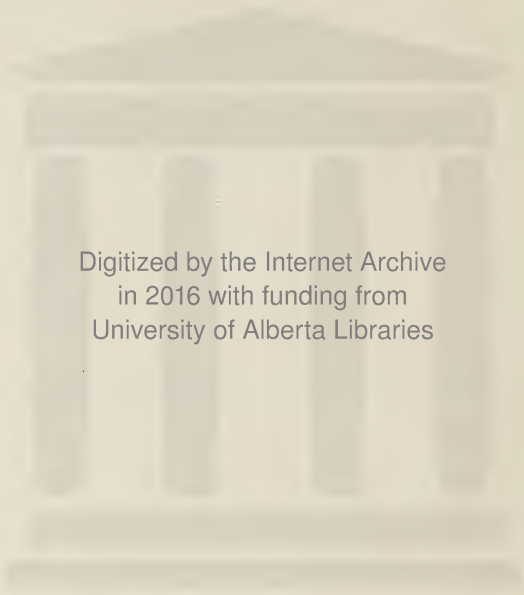


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# HIGH SCHOOL BIOLOGY

By

L. H. BAILEY AND WALTER M. COLEMAN

With an additional Chapter by G. V. Van Tausk  
following Botany Section, Pages 209 - 224.

NOTE—Chapter XVI Botany Section, and Chapters III,  
IV and V Zoology Section are not included in the  
Grade XII Course of Studies, and so may be omitted.

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BOUQUET OF BEARDED WHEAT



# BEGINNERS' BOTANY

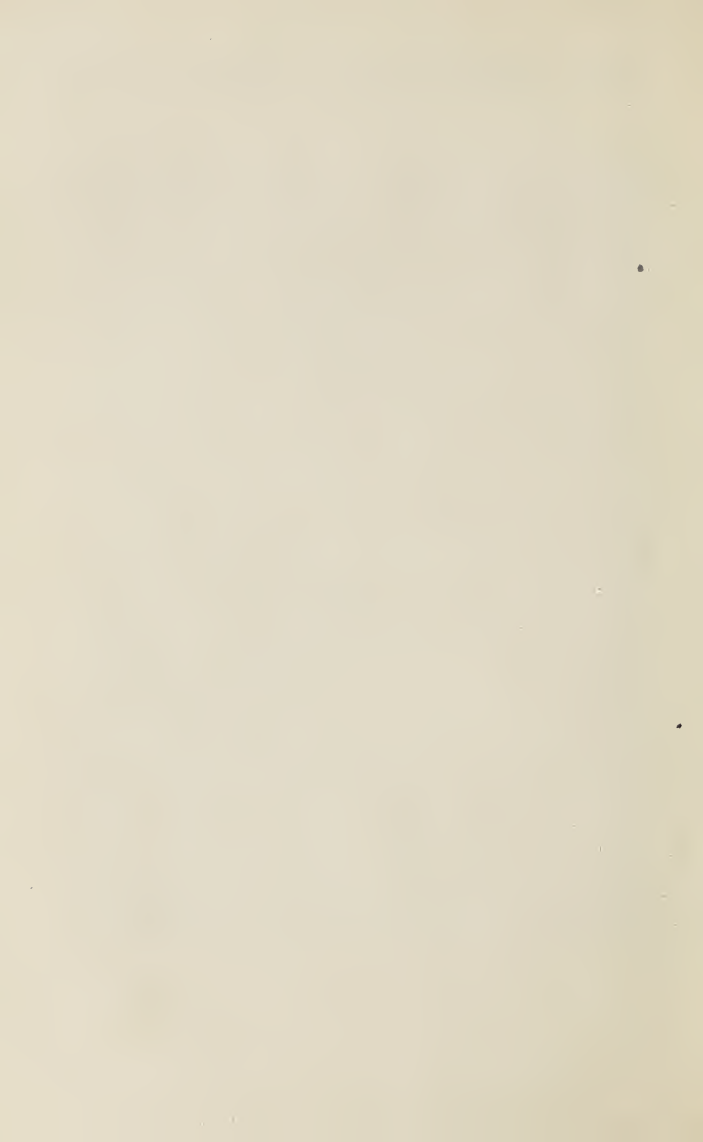
BY

L. H. BAILEY

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## PREFACE

IN all teaching of plants and animals to beginners, the plants themselves and the animals themselves should be made the theme, rather than any amount of definitions and of mere study in books. Books will be very useful in guiding the way, in arranging the subjects systematically, and in explaining obscure points; but if the pupil does not know the living and growing plants when he has completed his course in botany, he has not acquired very much that is worth the while.

It is well to acquaint the beginner at first with the main features of the entire plant rather than with details of its parts. He should at once form a mental picture of what the plant is, and what are some of its broader adaptations to the life that it leads. In this book, the pupil starts with the entire branch or the entire plant. It is sometimes said that the pupil cannot grasp the idea of struggle for existence until he knows the names and the uses of the different parts of the plant. This is an error, although well established in present-day methods of teaching.

Another very important consideration is to adapt the statement of any fact to the understanding of a beginner. It is easy, for example, to fall into technicalities when discussing osmosis; but the minute explanations would mean nothing to the beginner and their use would tend to confuse the picture which it is necessary to leave in the pupil's mind. Even the use of technical forms of expression would probably not go far enough to satisfy the trained physicist.



It is impossible ever to state the last thing about any proposition. All knowledge is relative. What is very elementary to one mind may be very technical and advanced to another. It is neither necessary nor desirable to safeguard statements to the beginner by such qualifications as will make them satisfactory to the critical expert in science. The teacher must understand that while accuracy is always essential, the *degree of statement* is equally important when teaching beginners.

The value of biology study lies in the work with the actual objects. It is not possible to provide specimens for every part of the work, nor is it always desirable to do so; for the beginning pupil may not be able to interest himself in the objects, and he may become immersed in details before he has arrived at any general view or reason of the subject. Great care must be exercised that the pupil is not swamped. Mere book work or memory stuffing is useless, and it may dwarf or divert the sympathies of active young minds.

The present tendency in secondary education is away from the formal technical completion of separate subjects and toward the developing of a workable training in the activities that relate the pupil to his own life. In the natural science field, the tendency is to attach less importance to botany and zoology as such, and to lay greater stress on the processes and adaptations of life as expressed in plants and animals. Education that is not applicable, that does not put the pupil into touch with the living knowledge and the affairs of his time, may be of less educative value than the learning of a trade in a shop.\* We are beginning to learn that the ideals and the abilities should be developed out of the common surroundings and affairs

of life rather than imposed on the pupil as a matter of abstract unrelated theory.

It is much better for the beginning pupil to acquire a real conception of a few central principles and points of view respecting common forms that will enable him to tie his knowledge together and organize it and apply it, than to familiarize himself with any number of mere facts about the lower forms of life which, at the best, he can know only indirectly and remotely. If the pupil wishes to go farther in later years, he may then take up special groups and phases.





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# BEGINNERS' BOTANY

## CHAPTER I

### NO TWO PLANTS OR PARTS ARE ALIKE

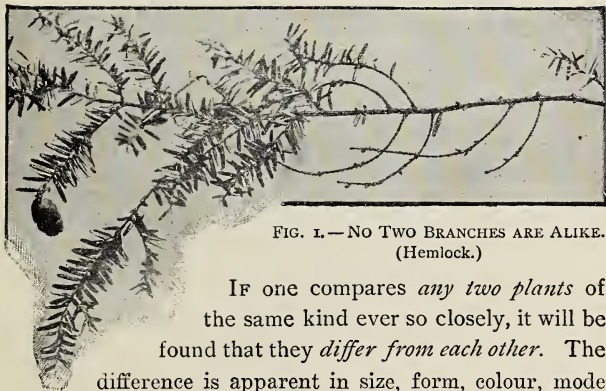


FIG. 1.—NO TWO BRANCHES ARE ALIKE.  
(Hemlock.)

IF one compares *any two plants* of the same kind ever so closely, it will be found that they *differ from each other*. The difference is apparent in size, form, colour, mode of branching, number of leaves, number of flowers, vigour, season of maturity, and the like; or, in other words, all plants and animals vary from an assumed or standard type.

If one compares *any two branches or twigs* on a tree, it will be found that they differ in size, age, form, vigour, and in other ways (Fig. 1).

If one compares *any two leaves*, it will be found that they are unlike in size, shape, colour, veining, hairiness, markings, cut of the margins, or other small features. In some cases (as in Fig. 2) the differences are so great as to be readily seen in a small black-and-white drawing.

If the pupil extends his observation to animals, he will still find the same truth; for probably *no two living objects are exact duplicates*. If any person finds two objects that he thinks to be exactly alike, let him set to work to



FIG. 2. — NO TWO LEAVES ARE ALIKE.

discover the differences, remembering that *nothing in nature is so small or apparently trivial as to be overlooked*.

**Variation**, or differences between organs and also between organisms, is one of the most significant facts in nature.

**SUGGESTIONS.**—The first fact that the pupil should acquire about plants is that no two are alike. The way to apprehend this great fact is to see a plant accurately and then to compare it with

another plant of the same species or kind. In order to direct and concentrate the observation, it is well to set a certain number of attributes or marks or qualities to be looked for. 1. Suppose any two or more plants of corn are compared in the following points, the pupil endeavouring to determine whether the parts exactly agree. See that the observation is close and accurate. Allow no guesswork. Instruct the pupil to measure the parts when size is involved.

- (1) Height of the plant.
- (2) Does it branch? How many secondary stems or "suckers" from one root?
- (3) Shade or colour.
- (4) How many leaves.
- (5) Arrangement of leaves on stem.
- (6) Measure length and breadth of six main leaves.
- (7) Number and position of ears; colour of silks.
- (8) Size of tassel, and number and size of its branches.
- (9) Stage of maturity or ripeness of plant.
- (10) Has the plant grown symmetrically, or has it been crowded by other plants or been obliged to struggle for light or room?
- (11) Note all unusual or interesting marks or features.
- (12) Always make note of comparative vigour of the plants.

NOTE TO TEACHER. — The teacher should always insist on *personal work* by the pupil. Every pupil should *handle and study the object by himself*. Books and pictures are merely guides and helps. So far as possible, study the plant or animal *just where it grows naturally*.

**Notebooks.** — Insist that the pupils make full notes and preserve these notes in suitable books. Note-taking is a powerful aid in organizing the mental processes, and in insuring accuracy of observation and record. The pupil should draw what he sees, even though he is not expert with the pencil. The drawing should not be made for looks, but to aid the pupil in his orderly study of the object; it should be a means of self-expression.

## CHAPTER II

### THE STRUGGLE TO LIVE

EVERY plant and animal is *exposed to unfavourable conditions*. It is obliged to contend with these conditions in order to live.

No two plants or parts of plants are identically exposed to the conditions in which they live. The large branches



FIG. 3.—A BATTLE FOR LIFE.

in Fig. 1 probably had more room and a better exposure to light than the smaller ones. Probably no two of the leaves in Fig. 2 are equally exposed to light, or enjoy identical advantages in relation to the food that they receive from the tree.

Examine any tree to determine under what advantages or disadvantages any of the limbs may live. Examine similarly the different plants in a garden row (Fig. 3); or the different bushes in a thicket; or the different trees in a wood.

The plant meets its conditions by succumbing to them (that is, by dying), or by adapting itself to them.

The tree meets the cold by ceasing its active growth, hardening its tissues, dropping its leaves. Many herbaceous or soft-stemmed plants meet the cold by dying to the ground and withdrawing all life into the root parts. Some plants meet the cold by dying outright and providing abundance of seeds to perpetuate the kind next season.



FIG. 4.—THE REACH FOR LIGHT OF A TREE ON THE EDGE OF A WOOD.

Plants adapt themselves to light by growing toward it (Fig. 4); or by hanging their leaves in such position that they catch the light; or in less sunny places, by expanding their leaf surface, or by greatly lengthening their stems so as to overtop their fellows, as do trees and vines.

The adaptations of plants will afford a fertile field of study as we proceed.

Struggle for existence and adaptation to conditions are among the most significant facts in nature.

The sum of all the conditions in which a plant or an animal is placed is called its environment, that is, its surroundings. The environment comprises the conditions of climate, soil, moisture, exposure to light, relation to food supply, contention with other plants or animals. *The organism adapts itself to its environment, or else it weakens or dies.* Every weak branch or plant has undergone some hardship that it was not wholly able to withstand.

SUGGESTIONS.—The pupil should study any plant, or branch of a plant, with reference to the position or condition under which it grows, and compare one plant or branch with another. With animals, it is common knowledge that every animal is alert to avoid or to escape danger, or to protect itself. 2. It is well to begin with a branch of a tree, as in Fig. 1. Note that no two parts are alike (Chap. I). Note that some are large and strong and that these stand farthest toward light and room. Some are very small and weak, barely able to live under the competition. Some have died. The pupil can easily determine which of the dead branches perished first. He should take note of the position or place of the branch on the tree, and determine whether the greater part of the dead twigs are toward the centre of the tree top or toward the outside of it. Determine whether accident has overtaken any of the parts. 3. Let the pupil examine the top of any thick old apple tree, to see whether there is any struggle for existence and whether any limbs have perished. 4. If the pupil has access to a forest, let him determine why there are no branches on the trunks of the old trees. Examine a tree of the same kind growing in an open field. 5. A row of lettuce or other plants sown thick will soon show the competition between plants. Any fence row or weedy place will also show it. Why does the farmer destroy the weeds among the corn or potatoes? How does the florist reduce competition to its lowest terms? what is the result?



## CHAPTER III

### THE SURVIVAL OF THE FIT

THE plants that most perfectly meet their conditions are able to persist. They perpetuate themselves. Their offspring are likely to inherit some of the attributes that enabled them successfully to meet the battle of life. The fit (those best adapted to their conditions) tend to survive.

Adaptation to conditions depends on the fact of variation; that is, if plants were perfectly rigid or invariable (all exactly alike) they could not meet new conditions. Conditions are necessarily new for every organism. It is impossible to picture a perfectly inflexible and stable succession of plants or animals.

**Breeding.** — Man is able to modify plants and animals. All our common domestic animals are very unlike their original ancestors. So all our common and long-cultivated plants have varied from their ancestors. Even in some plants that have been in cultivation less than a century the change is marked: compare the common black-cap raspberry with its common wild ancestor, or the cultivated blackberry with the wild form.



FIG. 5.—DESIRABLE AND UNDESIRABLE TYPES OF COTTON PLANTS. Why?

By choosing seeds from a plant that pleases him, the breeder may be able, under given conditions, to produce



FIG. 6.—FLAX BREEDING.

*A* is a plant grown for seed production;  
*B* for fibre production. Why?

selection of seed. He may select kernels from the best plant of corn in the field, and also from the poorest plant,—having reference not so much to mere incidental size and vigour of the plants that may be due to accidental conditions in the field, as to the apparently constitutional strength and size, number of ears, size of ears, perfectness of ears and kernels, habit of the plant as to suckering, and the like. The seeds may be saved and sown the next year. Every crop can no doubt be very greatly improved by a careful process of selection extending over a series of years. Crops are increased in yield or efficiency in three ways: 1, better general care; 2, enriching the land in which they grow; 3, attention to breeding.

numbers of plants with more or less of the desired qualities; from the best of these, he may again choose; and so on until the race becomes greatly improved (Figs. 5, 6, 7). This process of continuously choosing the most suitable plants is known as selection. A somewhat similar process proceeds in wild nature, and it is then known as natural selection.

#### SUGGESTIONS.

—6. Every pupil should undertake at least one simple experiment in se-



FIG. 7.—BREEDING.

*A*, effect from breeding from smallest grains (after four years), average head; *B*, result from breeding from the plumpest and heaviest grains (after four years), average head.

## CHAPTER IV

### PLANT SOCIETIES

IN the long course of time in which plants have been accommodating themselves to the varying conditions in which they are obliged to grow, *they have become adapted to every different environment*. Certain plants, therefore, may live together or near each other, all enjoying the same general conditions and surroundings. These aggregations of plants that are adapted to similar general conditions are known as plant societies.

Moisture and temperature are the leading factors in determining plant societies. The great geographical societies or aggregations of the plant world may conveniently be associated chiefly with the moisture supply, as: wet-region societies, comprising aquatic and bog vegetation (Fig. 8); arid-region societies, comprising desert and most sand-region vegetation; mid-region societies, comprising the mixed vegetation in intermediate regions (Fig. 9), this being the commonest type. Much of the characteristic scenery of any place is due to its plant societies. Arid-region plants usually have small and hard leaves, apparently preventing too rapid loss of water. Usually, also, they are characterized by stiff growth, hairy covering, spines, or a much-contracted plant-body, and often by large underground parts for the storage of water.

Plant societies may also be distinguished with reference to latitude and temperature. There are tropical societies, temperate-region societies, boreal or cold-region societies.

With reference to altitude, societies might be classified as *lowland* (which are chiefly wet-region), *intermediate* (chiefly mid-region), *subalpine* or *mid-mountain* (which are chiefly boreal), *alpine* or *high-mountain*.

The above classifications have reference chiefly to great geographical floras or societies. But there are societies within societies. There are small societies coming within the experience of every person who has ever seen plants



FIG. 8. — A WET-REGION SOCIETY.

growing in natural conditions. There are roadside, fence-row, lawn, thicket, pasture, dune, woods, cliff, barn-yard societies. Every different place has its characteristic vegetation. Note the smaller societies in Figs. 8 and 9. In the former is a water-lily society and a cat-tail society. In the latter there are grass and bush and woods societies.

**Some Details of Plant Societies.** — Societies may be composed of scattered and intermingled plants, or of dense clumps or groups of plants. Dense clumps or groups are usually made up of one kind of plant, and they are then

called colonies. Colonies of most plants are transient: after a short time other plants gain a foothold amongst them, and an intermingled society is the outcome. Marked exceptions to this are grass colonies and forest colonies, in which one kind of plant may hold its own for years and centuries.

In a large newly cleared area, plants usually first establish themselves in dense colonies. Note the great patches

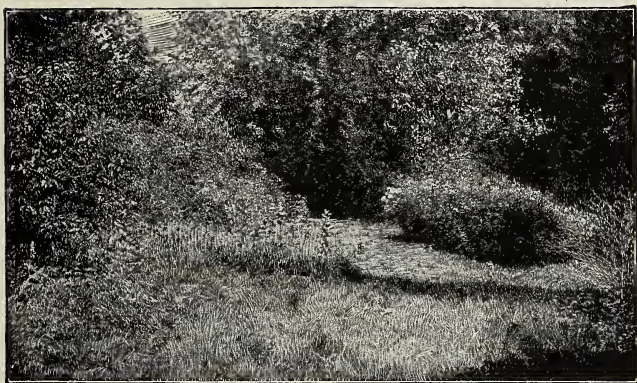


FIG. 9.—A MID-REGION SOCIETY.

of nettles, jewel-weeds, smart-weeds, clot-burs, fire-weeds in recently cleared but neglected swales, also the fire-weeds in recently burned areas, the rank weeds in the neglected garden, and the ragweeds and May-weeds along the recently worked highway. The competition amongst themselves and with their neighbours finally breaks up the colonies, and a mixed and intermingled flora is generally the result.

In many parts of the world the general tendency of neglected areas is to run into forest. All plants rush for the



cleared area. Here and there bushes gain a foothold. Young trees come up; in time these shade the bushes and gain the mastery. Sometimes the area grows to poplars or birches, and people wonder why the original forest trees do not return; but these forest trees may be growing unobserved here and there in the tangle, and in the slow processes of time the poplars perish—for they are short-lived—and the original forest may be replaced. Whether one kind of forest or another returns will depend partly on the kinds that are most seedful in that vicinity and which, therefore, have sown themselves most profusely. Much depends, also, on the kind of undergrowth that first springs up, for some young trees can endure more or less shade than others.

Some plants associate. They grow together. This is possible largely because they diverge or differ in charac-

ter. Plants associate in two ways:  
by growing side by side;  
by growing above or beneath.

In sparsely populated societies, plants may grow alongside each other. In most cases, however,  
there is overgrowth  
and undergrowth:



FIG. 10. — OVERGROWTH AND UNDERGROWTH IN THREE SERIES, — trees, bushes, grass.

one kind grows beneath another. Plants that have become adapted to shade are usually undergrowths. In a cat-tail swamp, grasses and other narrow-leaved plants grow in the bottom, but they are usually unseen by the casual

observer. Note the undergrowth in woods or under trees (Fig. 10). Observe that in pine and spruce forests there is almost no undergrowth, partly because there is very little light.

On the same area the societies may differ at different times of the year. There are spring, summer, and fall societies. The knoll which is cool with grass and strawberries in June may be aglow with goldenrod in September. If the bank is examined in May, look for the young plants that are to cover it in July and October; if in September, find the dead stalks of the flora of May. What succeeds the skunk cabbage, hepaticas, trilliums, phlox, violets, buttercups of spring? What precedes the wild sunflowers, ragweed, asters, and goldenrod of fall?

**The Landscape.**—To a large extent the colour of the landscape is determined by the character of the plant societies. Evergreen societies remain green, but the shade of green varies from season to season; it is bright and soft in spring, becomes dull in midsummer and fall, and assumes a dull yellow-green or a black-green in winter. Deciduous societies vary remarkably in colour—from the dull browns and grays of winter to the brown greens and olive-greens of spring, the staid greens of summer, and the brilliant colours of autumn.

The autumn colours are due to intermingled shades of green, yellow and red. The coloration varies with the kind of plant, the special location, and the season. Even in the same species or kind, individual plants differ in colour; and this individuality usually distinguishes the plant year by year. That is, an oak which is maroon red this autumn is likely to exhibit that range of colour every year. The autumn colour is associated with the natural maturity and death of the leaf, but it is most brilliant in long and open

falls — largely because the foliage ripens more gradually and persists longer in such seasons. It is probable that the autumn tints are of no utility to the plant. Autumn colours are not caused by frost. Because of the long, dry falls and the great variety of plants, the autumnal colour of the American landscape is phenomenal.

**Ecology.** — The study of the relationships of plants and animals to each other and to seasons and environments is known as ecology (still written *oecology* in the dictionaries). It considers the habits, habitats, and modes of life of living things — the places in which they grow, how they migrate or are disseminated, means of collecting food, their times and seasons of flowering, producing young, and the like.

**SUGGESTIONS.** — One of the best of all subjects for school instruction in botany is the study of plant societies. It adds definiteness and zest to excursions. 7. Let each excursion be confined to one or two societies. Visit one day a swamp, another day a forest, another a pasture or meadow, another a roadside, another a weedy field, another a cliff or ravine. Visit shores whenever possible. Each pupil should be assigned a bit of ground — say 10 or 20 ft. square — for special study. He should make a list showing (1) how many kinds of plants it contains, (2) the relative abundance of each. The lists secured in different regions should be compared. It does not matter greatly if the pupil does not know all the plants. He may count the kinds without knowing the names. It is a good plan for the pupil to make a dried specimen of each kind for reference. The pupil should endeavour to discover why the plants grow as they do. Note what kinds of plants grow next each other; and which are undergrowth and which overgrowth; and which are erect and which wide-spreading. *Challenge every plant society.*



## CHAPTER V

### THE PLANT BODY

**The Parts of a Plant.** — Our familiar plants are made up of several distinct parts. The most prominent of these parts are root, stem, leaf, flower, fruit, and seed. *Familiar plants differ wonderfully in size and shape*, — from fragile mushrooms, delicate waterweeds and pond-scums, to floating leaves, soft grasses, coarse weeds, tall bushes, slender climbers, gigantic trees, and hanging moss.

**The Stem Part.** — In most plants there is a main central part or shaft on which the other or *secondary parts* are borne. This main part is the plant axis. Above ground, in most plants, the main plant axis bears the branches, leaves, and flowers; below ground, it bears the roots.

The rigid part of the plant, which persists over winter and which is left after leaves and flowers are fallen, is the framework of the plant. The framework is composed of both root and stem. When the plant is dead, the framework remains for a time, but it slowly decays. The dry winter stems of weeds are the framework, or skeleton of the plant (Figs. 11 and 12). The framework of trees is the most conspicuous part of the plant.

**The Root Part.** — The root bears the stem at its apex, but otherwise it normally bears only root-branches. The stem, however, bears leaves, flowers, and fruits. Those living surfaces of the plant which are most exposed to light are green or highly coloured. The root tends to grow downward, but the stem tends to grow upward toward light

and air. The plant is anchored or fixed in the soil by the roots. Plants have been called "earth parasites."

**The Foliage Part.** — The leaves precede the flowers in point of time or life of the plant. The flowers always precede the fruits and seeds. Many plants die when the seeds have matured. The whole mass of leaves of any

plant or any branch is known as its *foliage*. In some cases, as in crocuses, the flowers seem to precede the leaves; but the leaves that made the food for these flowers grew the preceding year.



FIG. 11. — PLANT OF A  
WILD SUNFLOWER.



FIG. 12. — FRAME-  
WORK OF FIG. 11.

**The Plant Generation.** — The course of a plant's life, with all the events through which the plant naturally passes, is known as the plant's life-history. The life-history embraces various stages, or epochs, as *dormant*

*seed, germination, growth, flowering, fruiting.* Some plants run their course in a few weeks or months, and some live for centuries.

The entire life-period of a plant is called a generation. It is the whole period from birth to normal death, without reference to the various stages or events through which it passes.

A generation begins with the young seed, not with germi-

nation. It ends with death — that is, when no life is left in any part of the plant, and only the seed or spore remains to perpetuate the kind. In a bulbous plant, as a lily or an onion, the generation does not end until the bulb dies, even though the top is dead.

When the generation is of only one season's duration, the plant is said to be annual. When it is of two seasons, it is biennial. Biennials usually bloom the second year. When of three or more seasons, the plant is perennial. Examples of annuals are pigweed, bean, pea, garden sunflower; of biennials, evening primrose, mullein, teasel; of perennials, dock, most meadow grasses, cat-tail, and all shrubs and trees.

Duration of the Plant Body. — Plant structures which are more or less soft and which die at the close of the season are said to be herbaceous, in contradistinction to being <sup>opposite</sup> lignaceous or woody. A plant which is herbaceous to the ground is called an herb; but an herb may have a woody or perennial root, in which case it is called an herbaceous perennial. Annual plants are classed as herbs. Examples of herbaceous perennials are buttercups, bleeding heart, violet, waterlily, Bermuda grass, horse-radish, dock, dandelion, goldenrod, asparagus, rhubarb, many wild sunflowers (Figs. 11, 12).

Many herbaceous perennials have short generations. They become weak with one or two seasons of flowering and gradually die out. Thus, red clover usually begins to fail after the second year. Gardeners know that the best bloom of hollyhock, larkspur, pink, and many other plants, is secured when the plants are only two or three years old.

Herbaceous perennials which die away each season to bulbs or tubers, are sometimes called pseud-annuals (that

is, false annuals). Of such are lily, crocus, onion, potato, and bull nettle.

True annuals reach old age the first year. Plants which are normally perennial may become annual in a shorter-season climate by being killed by frost, rather than by dying naturally at the end of a season of growth. They are climatic annuals. Such plants are called plur-annuals in the short-season region. Many tropical perennials are plur-



FIG. 13.—A SHRUB OR BUSH. Dogwood osier.

annuals when grown in the north, but they are treated as true annuals because they ripen sufficient of their crop the same season in which the seeds are sown to make them worth cultivating, as tomato, red pepper, castor bean, cotton. Name several vegetables that are planted in gardens with the expectation that they will bear till frost comes.

Woody or ligneous plants usually live longer than herbs. Those that remain low and produce several or

many similar shoots from the base are called shrubs, as lilac, rose, elder, osier (Fig. 13). Low and thick shrubs are bushes. Plants that produce one main trunk and a more or less elevated head are trees (Fig. 14). All shrubs and trees are perennial.

Every plant makes an effort to propagate, or to perpetuate its kind; and, as far as we can see, this is the end for which the plant itself lives. The seed or spore is the final product of the plant.



FIG. 14. — A TREE. The weeping birch.

SUGGESTIONS. — 8. The teacher may assign each pupil to one plant in the school yard, or field, or in a pot, and ask him to bring out the points in the lesson. 9. The teacher may put on the board the names of many common plants and ask the pupils to classify into annuals, pseud-annuals, plur-annuals (or climatic annuals), biennials, perennials, herbaceous perennials, ligneous perennials, herbs, bushes, trees. Every plant grown on the farm should be so classified: wheat, oats, corn, buckwheat, timothy, strawberry, raspberry, currant, tobacco, alfalfa, flax, crimson clover, hops, cowpea, field bean, sweet potato, peanut, radish, sugar-cane, barley, cabbage, and others. Name all the kinds of trees you know.

## CHAPTER VI

### SEEDS AND GERMINATION

THE seed contains a miniature plant, or embryo. The embryo usually has three parts that have received names: the stemlet, or caulicle; the seed-leaf, or cotyledon (usually 1 or 2); the bud, or plumule, lying between or above the cotyledons. These parts are well



FIG. 15.—PARTS OF THE BEAN.

R, cotyledon; O, caulicle; A, plumule; F, first node.

seen in the common bean (Fig. 15), particularly when the seed has been soaked for a few hours. One of the large cotyledons — comprising half of the bean — is shown at R. The caulicle is at O. The plumule is shown at A. The cotyledons are attached to the caulicle at F: this point may be taken as the first node or joint.

**The Number of Seed-leaves.** — All plants having two seed-leaves belong to the group called dicotyledons. Such seeds in many cases split readily in halves, e.g. a bean. Some plants have only one seed-leaf in a seed. They form a group of plants called monocotyledons. Indian corn is an example of a plant with only one seed-leaf: a grain of corn does not split into halves as a bean does. Seeds of the pine family contain more than two cotyledons, but for our purposes they may be associated with the dicotyledons, although really forming a different group.

These two groups — the dicotyledons and the monocotyledons — represent two great natural divisions of the vegetable kingdom. The dicotyledons contain the woody



bark-bearing trees and bushes (except conifers), and most of the herbs of temperate climates except the grasses, sedges, rushes, lily tribes, and orchids. The flower-parts are usually in fives or multiples of five, the leaves mostly netted-veined, the bark or rind distinct, and the stem often bearing a pith at the centre. The monocotyledons usually have the flower-parts in threes or multiples of three, the leaves long and parallel-veined, the bark not separable, and the stem without a central pith.

Every seed is provided with food to support the germinating plant. Commonly this food is starch. The food may be stored in the cotyledons, as in bean, pea, squash; or outside the cotyledons, as in castor bean, pine, Indian corn. When the food is outside or around the embryo, it is usually called endosperm.

**Seed-coats; Markings on Seed.** — The embryo and endosperm are inclosed within a covering made of two or more layers and known as the seed-coats. Over the point of the caulicle is a minute hole or a thin place in the coats known as the micropyle. This is the point at which the pollen-tube entered the forming ovule and through which the caulicle breaks in germination. The micropyle is shown at *M* in Fig. 16. The scar where the seed broke from its funiculus (or stalk that attached it to its pod) is named the hilum. It occupies a third of the length of the bean in Fig. 16. The hilum and micropyle are always present in seeds, but they are not always close together. In many cases it is difficult to identify the micropyle in the dormant seed, but its location is at once shown by the protruding caulicle as germination begins. Opposite the micropyle in the bean (at the other end of the hilum) is an elevation known as the raphe.



FIG. 16. — EXTERNAL PARTS OF BEAN.

This is formed by a union of the funiculus, or seed-stalk, with the seed-coats, and through it food was transferred for the development of the seed, but it is now functionless.

Seeds differ wonderfully in size, shape, colour, and other characteristics. They also vary in longevity. These characteristics are *peculiar to the species or kind*. Some seeds maintain life only a few weeks or even days, whereas others will "keep" for ten or twenty years. In special cases, seeds have retained vitality longer than this limit, but the stories that live seeds, several thousand years old, have been taken from the wrappings of mummies are unfounded.

**Germination.** — The embryo is not dead ; it is only dormant. When supplied with moisture, warmth, and oxygen (air), it awakes and grows: this growth is germination. The embryo lives for a time on the stored food, but gradually the plantlet secures a foothold in the soil and gathers food for itself. When the plantlet is finally able to shift for itself, germination is complete.

**Early Stages of Seedling.** — The germinating seed first absorbs water, and swells. The starchy matters gradually become soluble. The seed-coats are ruptured, the caulicle and plumule emerge. During this process the seed respire freely, throwing off carbon dioxide ( $\text{CO}_2$ ).

The caulicle usually elongates, and from its lower end roots are emitted. The elongating caulicle is known as the hypocotyl ("below the cotyledons"). That is, the hypocotyl is that part of the stem of the plantlet lying between the roots and the cotyledon. The general direction of the young hypocotyl, or emerging caulicle, is downwards. As soon as roots form, it becomes fixed and its subsequent growth tends to raise the cotyledons above the ground, as in the bean. When cotyledons rise into the



air, germination is said to be epigeal ("above the earth"). Bean and pumpkin are examples. When the hypocotyl does not elongate greatly and the cotyledons remain under ground, the germination is hypogeal ("beneath the earth"). Pea and scarlet runner bean are examples (Fig. 48). When the germinating seed lies on a hard surface, as on closely compacted soil, the hypocotyl and rootlets may not be able to secure a foothold and they assume grotesque forms (Fig. 17). Try this with peas and beans.

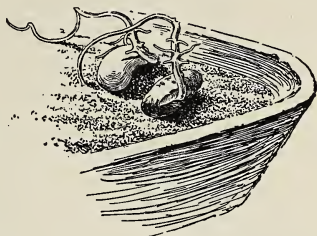


FIG. 17. — PEA. Grotesque forms assumed when the roots cannot gain entrance to the soil.

The first internode ("between nodes") above the cotyledons is the epicotyl. It elevates the plumule into the air, and the plumule-leaves expand into the first true leaves of the plant. These first true leaves, however, may be very unlike the later leaves in shape.

**Germination of Bean.** — The common bean, as we have seen (Fig. 15), has cotyledons that occupy all the space inside the seed-coats. When the hypocotyl, or elongated caulicle, emerges, the plumule-leaves have begun to enlarge, and to unfold (Fig. 18). The hypocotyl elongates rapidly. One end of it is held by the roots. The other is held by the seed-coats in the soil. It therefore takes the form of a loop, and the central part of the loop "comes up" first (*a*, Fig. 19). Presently the cotyledons come out of the seed-coats,



FIG. 18. — COTYLEDONS OF GERMINATING BEAN SPREAD APART TO SHOW ELONGATING CAULICLE AND PLUMULE.



FIG. 19. — GERMINATION OF BEAN.

and the plant straightens and the cotyledons expand. These cotyledons, or "halves of the bean," persist for some time (*b*, Fig. 19). They often become green and probably perform some function of foliage. Because of its large size, the Lima bean shows all these parts well.

### Germination of Castor Bean. —

In the castor bean the hilum and micropyle are at the smaller end (Fig. 20). The bean "comes up" with a loop, which indicates that the hypocotyl greatly elongates. On examining germinating seed, however, it will be found that the cotyledons are contained inside a fleshy body, or sac (*a*, Fig. 21). This sac is the endosperm. Against its inner surface the thin, veiny cotyledons are very closely pressed, ab-



FIG. 20. — SPROUTING OF CASTOR BEAN.



FIG. 21. — GERMINATION OF CASTOR BEAN.

Endosperm at *a*.



FIG. 22. — CASTOR BEAN.

Endosperm at *a, a*; cotyledons at *b*.



FIG. 23. — GERMINATION COMPLETE IN CASTOR BEAN.

sorbing its substance (Fig. 22). The cotyledons increase in size as they reach the air (Fig. 23), and become functional leaves.

**Germination of Monocotyledons.**—Thus far we have studied dicotyledonous seeds; we may now consider the monocotyledonous group. Soak kernels of corn. Note that the micropyle and hilum are at the smaller end (Fig. 24).

Make a longitudinal section through the narrow diameter; Fig. 25 shows it. The



FIG. 24.—SPROUTING INDIAN CORN.

Hilum at *h*; micropyle at *d*.



FIG. 25.—KERNEL OF INDIAN CORN.

Caulicle at *b*; cotyledon at *a*; plumule at *p*.

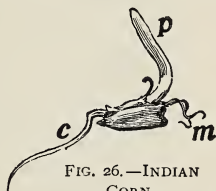


FIG. 26.—INDIAN CORN.

Caulicle at *c*; roots emerging at *m*; plumule at *p*.

single cotyledon is at *a*, the caulicle at *b*, the plumule at *p*. The cotyledon remains in the seed. The food is stored both in the cotyledon and as endosperm, chiefly the latter. The emerging shoot is the plumule, with a sheathing leaf (*p*, Fig. 26). The root is emitted from the tip of the caulicle, *c*. The caulicle is held in a sheath (formed mostly from the seed-coats), and some of the roots escape through the upper end

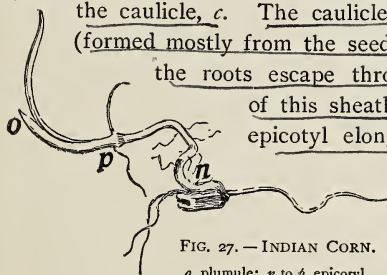


FIG. 27.—INDIAN CORN.  
*o*, plumule; *n* to *p*, epicotyl.

of this sheath (*m*, Fig. 26). The epicotyl elongates, particularly if the seed is planted deep or if it is kept for a time confined. In Fig. 27 the epicotyl has elongated from *n* to *p*. The true plumule-leaf is at *o*, but other leaves grow from its sheath. In Fig. 28 the roots are seen emerging from the two ends of the caulicle.

sheath, *c*, *m*; the epicotyl has grown to *p*; the first plumule-leaf is at *o*.

In studying corn or other fruits or seeds, the pupil should note how the seeds are arranged, as on the cob. Count the

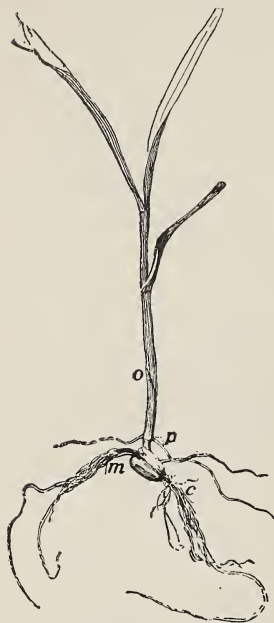


FIG. 28. — GERMINATION IS COMPLETE.

*p*, top of epicotyl; *o*, plumule-leaf;  
*m*, roots; *c*, lower roots.

rows on a corn cob. Odd or even in number? Always the same number? The silk is the style: find where it was attached to the kernel. Did the ear have any coverings? Explain. Describe colours and markings of kernels of corn; and of peas, beans, castor bean.

**Gymnosperms.** — The seeds in the pine cone, not being inclosed in a seed-vessel, readily fall out when the cone dries and the scales separate. Hence it is difficult to find cones with seeds in them after autumn has passed (Fig. 29). The cedar is also a gymnosperm.

Remove a scale from a pine cone and draw it and the seeds as they lie in place on the upper side of the scale.

Examine the seed, preferably with a magnifying glass. Is there a hilum? The micropyle is at the bottom or little end of the seed. Toss a seed upward into the air. Why does it fall so slowly? Can you explain the peculiar whirling motion by the shape of the wing? Repeat the ex-

periment in the wind. Remove the wing from a seed and toss it and an uninjured seed into the air together. What do you infer from these experiments?

**SUGGESTIONS.** — Few subjects connected with the study of plant-life are so useful in schoolroom demonstrations as germination. The pupil should prepare the soil, plant the seeds, water them, and care for the plants. **10.** Plant seeds in pots or shallow boxes. The box should not be very wide or long, and not over four inches deep. Holes may be bored in the bottom so it will not hold water. Plant a number of squash, bean, corn, pine, or other seeds about an inch deep in damp sand or pine sawdust in this box. The depth of planting should be two to four times the diameter of the seeds. Keep the sand or sawdust moist but not wet. If the class is large, use several boxes, that the supply of specimens may be ample. Cigar boxes and chalk boxes are excellent for individual pupils. It is well to begin the planting of seeds at least ten days in advance of the lesson, and to make four or five different plantings at intervals. A day or two before the study is taken up, put seeds to soak in moss or cloth. The pupil then has a series from swollen seeds to complete germination, and all the steps can be made out. Dry seeds should be had for comparison. If there is no special room for laboratory, nor duplicate apparatus for every pupil, each experiment may be assigned to a committee of two pupils to watch in the schoolroom. **11.** Good seeds for study are those detailed in the lesson, and buckwheat, pumpkin, cotton, morning glory, radish, four o'clock, oats, wheat. It is best to use familiar seeds of farm and garden. Make drawings and notes of all the events in the germination. Note the effects of unusual conditions, as planting too deep and too shallow and different sides up. For hypogeal germination, use the garden pea, scarlet-runner, or Dutch



FIG. 29. — CONES OF HEMLOCK (ABOVE), WHITE PINE, PITCH PINE.

case-knife bean, acorn, horse-chestnut. Squash seeds are excellent for germination studies, because the cotyledons become green and leafy and germination is rapid. Onion is excellent, except that it germinates too slowly. In order to study the root development of germinating plantlets, it is well to provide a deeper box with a glass side against which the seeds are planted. **12.** Observe the germination of any common seed about the house premises. When elms, oaks, pines, or maples are abundant, the germination of their seeds may be studied in lawns and along fences. **13.** When studying germination the pupil should note the differences in shape and size between cotyledons and plumule leaves, and between plumule leaves and the normal leaves (Fig. 30). Make drawings. **14.** Make the tests described in the introductory experiments with bean, corn, the castor bean, and other seed for starch and proteids. Test flour, oatmeal,



FIG. 30. — MUSKMELON SEEDLINGS, with the unlike seed-leaves and true leaves.

rice, sunflower, four o'clock, various nuts, and any other seeds obtainable. Record your results by arranging the seeds in three classes, 1. Much starch (colour blackish or purple). 2. Little starch (pale blue or greenish), 3. No starch (brown or yellow). **15.** Rate of growth of seedlings as affected by differences in tempera-

ture. Pack soft wet paper to the depth of an inch in the bottom of four glass bottles or tumblers. Put ten soaked peas or beans into each. Cover each securely and set them in places having different temperatures that vary little. (A furnace room, a room with a stove, a room without stove but reached by sunshine, an unheated room not reached by the sun). Take the temperatures occasionally with the thermometer to find difference in temperature. The tumblers in warm places should be covered very tightly to prevent the germination from being retarded by drying out. Record the number of seeds which sprout in each tumbler within 1 day, 2 days, 3 days, 4 days, etc. **16.** Is air necessary for the germination and growth of seedlings? Place damp blotting paper in the bottom of a bottle and fill it three-fourths full of soaked seeds, and close it tightly with a rubber stopper or oiled cork. Prepare a "check experiment" by having another bottle with all conditions the same except that it is covered loosely that air may have access to it, and set the bottles side by side (why keep the bottles together?). Record results as in the



preceding experiment. **17. What is the nature of the gas given off by germinating seeds?** Fill a tin box or large-necked bottle with dry beans or peas, then add water; note how much they swell. Secure two fruit jars. Fill one of them a third full of beans and keep them moist. Allow the other to remain empty. In a day or two insert a lighted splinter or taper into each. In the empty jar the taper burns: it contains oxygen. In the seed jar the taper goes out: the air has been replaced by carbon dioxide. The air in the bottle may be tested for carbon dioxide by removing some of it with a rubber bulb attached to a glass tube (or a fountain-pen filler) and bubbling it through lime water. **18. Temperature.** Usually there is a perceptible rise in temperature in a mass of germinating seeds. This rise may be tested with a thermometer. **19. Interior of seeds.** Soak seeds for twenty-four hours and remove the coat. Distinguish the embryo from the endosperm. Test with iodine. **20. Of what utility is the food in seeds?** Soak some grains of corn overnight and remove the endosperm, being careful not to injure the fleshy cotyledon. Plant the incomplete and also some complete grains in moist sawdust and measure their growth at intervals. (Boiling the sawdust will destroy moulds and bacteria which might interfere with experiment.) Peas or beans may be sprouted on damp blotting paper; the cotyledons of one may be removed, and this with a normal seed equally advanced in germination may be placed on a perforated cork floating in water in a jar so that the roots extend into the water. Their growth may be observed for several weeks. **21. Effect of darkness on seeds and seedlings.** A box may be placed mouth downward over a smaller box in which seedlings are growing. The empty box should rest on half-inch blocks to allow air to reach the seedlings. Note any effects on the seedlings of this cutting off of the light. Another box of seedlings not so covered may be used as a check. Lay a plank on green grass and after a week note the change that takes place beneath it. **22. Seedling of pine.** Plant pine seeds. Notice how they emerge. Do the cotyledons stay in the ground? How many cotyledons have they? When do the cotyledons get free from the seed-coat? What is the last part of the cotyledon to become free? Where is the growing point or plumule? How many leaves appear at once? Does the new pine cone grow on old wood or on wood formed the same spring with the cone? Can you always find partly grown cones on pine trees in winter? Are pine cones when mature on two-year-old wood? How long do cones stay on a tree after the seeds have fallen out? What is the advantage of the seeds falling before the cones? **23. Home experiments.** If desired, nearly all of the fore-

going experiments may be tried at home. The pupil can thus make the drawings for the notebook at home. A daily record of measurements of the change in size of the various parts of the seedling should also be made. **24. Seed-testing.**—It is important that one know before planting whether seeds are good, or able to grow. A simple seed-tester may be made of two plates, one inverted over the other (Fig. 31). The lower plate is nearly filled with clean sand,



FIG. 31.—A HOME-MADE SEED-TESTER.

which is covered with cheese cloth or blotting paper on which the seeds are placed. Canton flannel is sometimes used in place of sand and blotting paper. The seeds are then covered with another blotter or piece of cloth, and water is applied until the sand and papers are saturated. Cover with the second plate. Set the plates where they will have about the temperature that the given seeds would require out of doors, or perhaps a slightly higher temperature.

Place 100 or more grains of clover, corn, wheat, oats, rye, rice, buckwheat, or other seeds in the tester, and keep record of the number that sprout. The result will give a percentage measure of the ability of the seeds to grow. Note whether all the seeds sprout with equal vigour and rapidity. Most seeds will sprout in a week or less. Usually such a tester must have fresh sand and paper after each test, for mould fungi are likely to breed in it. If canton flannel is used, it may be boiled. If possible, the seeds should not touch one another.

NOTE TO TEACHER.—With the study of germination, the pupil will need to begin dissecting.

For dissecting, one needs a lens for the examination of the smaller parts of plants and animals. It is best to have the lens mounted on a frame, so that the pupil has both hands free for pulling the part in pieces. An ordinary pocket lens may be mounted on a wire in a block as in Fig. A. A cork is slipped on the top of the wire to avoid injury to the face. The pupil should be provided with two dissecting needles (Fig. B), made by securing an ordinary needle in a pencil-like stick. Another convenient arrangement is shown in Fig. C. A small tin dish is used for the base. Into this a stiff wire standard is soldered. The dish is filled with solder to make it heavy and firm. Into a cork slipped on the standard, a cross wire is inserted, holding on the end a jeweller's



glass. The lens can be moved up and down and sidewise. This outfit can be made for about seventy-five cents. Fig. D shows a convenient hand-rest or dissecting-stand to be used under this lens. It may be 16 in. long, 4 in. high, and 4 or 5 in. broad.

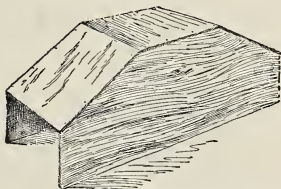
Various kinds of dissecting microscopes are on the market, and these are to be recommended when they can be afforded.



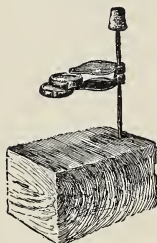
*B.*—DIS-  
SECTING  
NEEDLE  
 $\frac{1}{2}$  natural  
size.



*C.*—DISSECTING GLASS.



*D.*—DISSECTING STAND.



*A.*—IMPROVED  
STAND FOR LENS.

Instructions for the use of the compound microscope, with which some schools may be equipped, cannot be given in a brief space; the technique requires careful training. Such microscopes are not needed unless the pupil studies cells and tissues.

## CHAPTER VII

### THE ROOT—THE FORMS OF ROOTS

**The Root System.** — The offices of the root are 1. to hold the plant in place, and 2. to gather food. Not all the food materials, however, are gathered by the roots.



FIG. 32. — TAP-ROOT SYSTEM OF ALFALFA.



FIG. 33. — TAP-ROOT OF THE DANDELION.

The entire mass of roots of any plant is called its root system. The root system may be annual, biennial or perennial, herbaceous or woody, deep or shallow, large or small.

**Kinds of Roots.** — A strong leading central root, which runs directly downwards, is a tap-root. The tap-root forms

an axis from which the side roots may branch. The side or spreading roots are usually smaller. Plants that have such a root system are said to be tap-rooted. Examples are red clover, alfalfa, beet, turnip, radish, burdock, dandelion, hickory (Figs. 32, 33).

A fibrous root system is one that is composed of many nearly equal slender branches. The greater number of plants have fibrous roots. Examples are many common grasses, wheat, oats, corn. The buttercup in Fig. 34 has a fibrous root system. Many trees have a strong tap-root when very young, but after a while it ceases to extend strongly and the side roots develop until finally the tap-root character disappears.



FIG. 34.—A BUTTERCUP PLANT, with fibrous roots.

**Shape and Extent of the Root System.** — The depth to which roots extend depends on the kind of plant, and the nature of the soil. Of most plants the roots extend far in all directions and lie comparatively near the surface. The roots usually radiate from a common point just beneath the surface of the ground.

The roots grow here and there in search of food, often extending much farther in all directions than the spread of the top of the plant. Roots tend to spread farther in poor soil than in rich soil, for the same size of plant. The root has no such definite form as the stem has. Roots are usually very crooked, because they are constantly turned aside by obstacles. Examine roots in stony soil.

The extent of root surface is usually very large, for the feeding roots are fine and very numerous. An ordinary plant of Indian corn may have a total length of root (measured as if the roots were placed end to end) of several hundred feet.

The fine feeding roots are most abundant in the richest part of the soil. They are attracted by the food materials. Roots often will completely surround a bone or other morsel. When roots of trees are exposed, observe that most of them are horizontal and lie near the top of the ground. Some roots, as of willows, extend far in search of water. They often run into wells and drains, and into the margins of creeks and ponds. Grow plants in a long narrow box, in one end of which the soil is kept very dry and in the other moist: observe where the roots grow.

**Buttresses.** — With the increase in diameter, the upper roots often protrude above the ground and become bracing buttresses. These buttresses are usually largest in trees



FIG. 35. — THE BRACING BASE OF A FIELD PINE.

which always have been exposed to strong winds (Fig. 35). Because of growth and thickening, the roots elevate part of their diameter, and the washing away of the soil makes them to appear as if having risen out of the ground.

**Aërial Roots.** — Although roots usually grow underground, there are some that naturally grow above ground. These usually occur on climbing plants, the roots becoming supports or fulfilling the office of tendrils. These aërial roots usually turn away from the light, and therefore enter the

crevices and dark places of the wall or tree over which the plant climbs. The trumpet creeper (Fig. 36), true or English ivy, and poison ivy climb by means of roots.

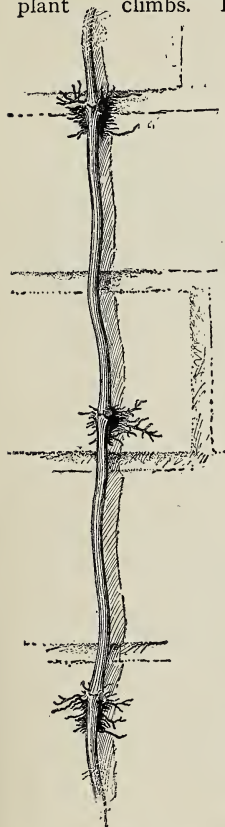


FIG. 36.—AËRIAL ROOTS OF TRUMPET CREEPER OR TECOMA.



FIG. 37.—AËRIAL ROOTS OF AN ORCHID.

In some plants all the roots are aërial; that is, the plant grows above ground, and the roots gather food from the air. Such plants usually grow on trees. They are known as epiphytes or air-plants. The most familiar examples are some of the tropical orchids which are grown in glass-

houses (Fig. 37). Rootlike organs of dodder and other parasites are discussed in a future chapter.

Some plants bear aërial roots, that may propagate the plant or may act as braces. They are often called **prop-roots**. The roots of Indian corn are familiar (Fig. 38). Many ficus trees, as the banyan of India, send out roots from their branches; when these roots reach the ground they take hold and become great trunks, thus spreading the



FIG. 38. — INDIAN CORN, showing the brace roots at oo.

top of the parent tree over large areas. The mangrove tree of the tropics grows along seashores and sends down roots from the overhanging branches (and from the fruits) into the shallow water, and thereby gradually marches into the sea. The tangled mass behind catches the drift, and soil is formed.

**Adventitious Roots.**— Sometimes roots grow from the stem or other unusual places as the result of some accident to the plant, being located without known method or law. They are called **adventitious** (chance) **roots**. Cuttings of the stems of roses, figs, geraniums, and other plants, when planted, send out adventitious roots and form new plants. The ordinary roots, or soil roots, are of course not classed as adventitious roots. The adventitious roots arise on occasion, and not as a normal or regular course in the growth of the plant.

No two roots are alike; that is, they vary among themselves as stems and leaves do. Each kind of plant has its



own form or habit of root (Fig. 39). Carefully wash away the soil from the roots of any two related plants, as oats and wheat, and note the differences in size, depth, direction, mode of branching, number of fibrils, colour, and other

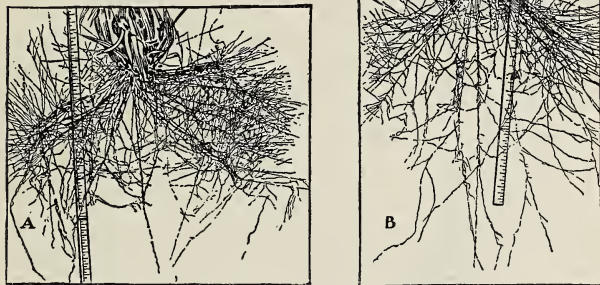


FIG. 39.—ROOTS OF BARLEY AT A AND CORN AT B.  
Carefully trace the differences.

features. The character of the root system often governs the treatment that the farmer should give the soil in which the plant or crop grows.

Roots differ not only in their form and habit, but also in colour of tissue, character of bark or rind, and other features. It is excellent practice to *try to identify different plants by means of their roots*. Let each pupil bring to school two plants with the roots very carefully dug up, as cotton, corn, potato, bean, wheat, rye, timothy, pumpkin, clover, sweet pea, raspberry, strawberry, or other common plants.

**Root Systems of Weeds.**—Some weeds are pestiferous because they seed abundantly, and others because their underground parts run deep or far and are persistent. Make out the root systems in the six worst weeds in your locality.



## CHAPTER VIII

### THE ROOT. — FUNCTION AND STRUCTURE

The function of roots is twofold, — 1. to provide support or anchorage for the plant, and 2. to collect and convey food materials. The first function is considered in Chapter VII; we may now give attention in more detail to the second.



FIG. 40. — WHEAT GROWING UNDER DIFFERENT SOIL TREATMENTS. Soil deficient in nitrogen; commercial nitrogen applied to pot 3 (on right).

The feeding surface of the roots is near their ends. As the roots become old and hard, they serve only as channels through which food passes and as hold-fasts or supports for the plant. The root-hold of a plant is very strong. Slowly pull upwards on some plant, and note how firmly it is anchored in the soil.

Roots have power to choose their food; that is, they do not absorb all substances with which they come in contact. They do not take up great quantities of useless or harmful materials, even though

these materials may be abundant in the soil; but they may take up a greater quantity of some of the plant-foods than the plant can use to advantage. Plants respond very quickly to liberal feeding, — that is, to the application of plant-food to the soil (Fig 40). The poorer the soil, the more marked are the results, as a rule, of the application

of fertilizers. Certain substances, as common salt, will kill the roots.

Roots absorb Substances only in Solution.—Substances cannot be taken in solid particles. These materials are in solution in the soil water, and the roots themselves also have the power to dissolve the soil materials to some extent by means of substances that they excrete. The materials that come into the plant through the roots are water and mostly the mineral substances, as compounds of potassium, iron, phosphorus, calcium, magnesium, sulphur, and chlorine. These mineral substances compose the ash when the plant is burned. The carbon is derived from the air through the green parts. Oxygen is derived from the air and the soil water.



FIG. 41.—NODULES ON ROOTS OF RED CLOVER.

Nitrogen enters through the Roots.

—All plants must have nitrogen; yet, although about four-fifths of the air is nitrogen, plants are not able, so far as we know, to take it in through their leaves. It enters through the roots in combination with other elements, chiefly in the form of nitrates (certain combinations with oxygen and a mineral base). The great family of leguminous plants, however (as peas, beans, cowpea, clover, alfalfa, vetch), use the nitrogen contained in the air in the soil. They are able to utilize it through the agency of nodules on their roots (Figs. 41, 42). These nodules contain bacteria, which appropriate the free or uncombined nitrogen and pass it on to the plant. The nitrogen

becomes incorporated in the plant tissue, so that these crops are high in their nitrogen content. Inasmuch as



FIG. 42. — NODULES ON VETCH.

nitrogen in any form is expensive to purchase in fertilizers, the use of leguminous crops to plough under is a very important agricultural practice in preparing the land for other crops. In order that leguminous crops may acquire atmospheric nitrogen more freely and thereby thrive better, the land is sometimes sown or inoculated with the nodule-forming bacteria.

**Roots require moisture** in order to serve the plant. The soil water that is valuable to the plant is not the free water, but the thin film of moisture which adheres to each little particle of soil. The finer the soil, the greater the number of particles, and therefore the greater is the quantity of film moisture that it can hold. This moisture surrounding the grains may not be perceptible, yet the plant can use it. Root absorption may continue in a soil which seems to be dust dry. Soils that are very hard and



FIG. 43. — TWO KINDS OF SOIL THAT HAVE BEEN WET AND THEN DRIED. The loamy soil above remains loose and capable of growing plants; the clay soil below has baked and cracked.

“baked” (Fig. 43) contain very little moisture or air,—not so much as similar soils that are granular or mellow.

**Proper Temperature for Root Action.**—*The root must be warm in order to perform its functions.* Should the soil of fields or greenhouses be much colder than the air, the plant suffers. When in a warm atmosphere, or in a dry atmosphere, plants need to absorb much water from the soil, and the roots must be warm if the root-hairs are to supply the water as rapidly as it is needed. *If the roots are chilled, the plant may wilt or die.*

**Roots need Air.**—Corn on land that has been flooded by heavy rains loses its green colour and turns yellow. *Besides diluting plant-food, the water drives the air from the soil, and this suffocation of the roots is very soon apparent in the general ill health of the plant.* Stirring or tilling the soil aerates it. Water plants and bog plants have adapted themselves to their particular conditions. They get their air either by special surface roots, or from the water through stems and leaves.

**Rootlets.**—*Roots divide into the thinnest and finest fibrils: there are roots and there are rootlets.* The smallest rootlets are so slender and delicate that they break off even when the plant is very carefully lifted from the soil.

*The rootlets, or fine divisions, are clothed with the root-hairs* (Figs. 44, 45, 46). *These root-hairs attach to the soil particles, and a great amount of soil is thus brought into actual contact with the plant.* These are very delicate prolonged surface cells of the roots. They are borne for a short distance just back of the tip of the root.

*Rootlet and root-hair differ.* The rootlet is a compact



FIG. 44. — ROOT-HAIRS OF THE RADISH.

cellular structure. The root-hair is a delicate tubular cell (Fig. 45), within which is contained living matter (protoplasm); and the protoplasmic lining membrane of the

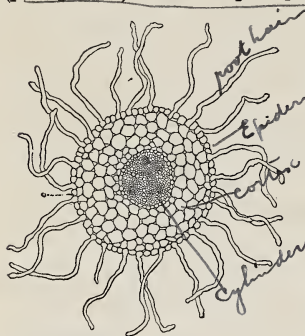


FIG. 45.—CROSS-SECTION OF ROOT, enlarged, showing root-hairs.

wall governs the entrance of water and substances in solution. Being long and tube-like, these root-hairs are especially adapted for taking in the largest quantity of solutions; and they are the principal means by which plant-food is absorbed from the soil, although the surfaces of the rootlets themselves do their part. Water plants do not produce an

abundant system of root-hairs, and such plants depend largely on their rootlets.

The root-hairs are very small, often invisible. They, with the young roots, are usually broken off when the plant is pulled up. They are best seen when seeds are germinated between layers of dark blotting paper or flannel. On the young roots they will be seen as a mould-like or gossamer-like covering. Root-hairs soon die: they do not grow into roots. New ones form as the root grows.

Osmosis.—The water with its nourishment goes through the thin walls of the root-hairs and rootlets by the process of osmosis. If there are two liquids of different density

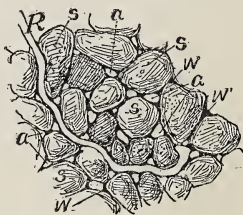


FIG. 46.—ROOT-HAIR, much enlarged, in contact with the soil particles (*s*). Air-spaces at *a*; water-films on the particles, as at *w*.



on the inside and outside of an organic (either vegetable or animal) membrane, the liquids tend to mix through the membrane. The law of osmosis is that the most rapid flow is toward the denser solution. The protoplasmic lining of the cell wall is such a membrane. The soil water being a weaker solution than the sap in the roots, the flow is into the root. A strong fertilizer sometimes causes a plant to wither, or "burns it." Explain.

**Structure of Roots.** — The root that grows from the lower end of the caulicle is the first or primary root. Secondary roots branch from the primary root. Branches of secondary roots are sometimes called tertiary roots. Do the secondary roots grow from the cortex, or from the central cylinder of the primary root? Trim or peel the cortex from a root and its branches and determine whether the branches still hold to the central cylinder of the main root.

**Internal Structure of Roots.** — A section of a root shows that it consists of a central cylinder (see Fig. 45) surrounded by a layer. This layer is called the cortex. The outer layer of cells in the cortex is called the epidermis, and some of the cells of the epidermis are prolonged and form the delicate root-hairs. The cortex resembles the bark of the stem in its nature. The central cylinder contains many tube-like canals, or "vessels" that convey water and food (Fig. 45). Cut a sweet potato across (also a radish and a turnip) and distinguish the central cylinder, cortex, and epidermis. Notice the hard cap on the tip of roots. Roots differ from stems in having no real pith.

**Microscopic Structure of Roots.** — Near the end of any young root or shoot the cells are found to differ from one another more or less, according to the distance from the point. This differentiation takes place in the region just back of the growing point. To study growing points, use

the hypocotyl of Indian corn which has grown about one-half inch. Make a longitudinal section. Note these points (Fig. 47): (*a*) the tapering root-cap beyond the growing point; (*b*) the blunt end of the root proper and the rectangular shape of the cells found there; (*c*) the group of cells in the middle of the first layers beneath the root-

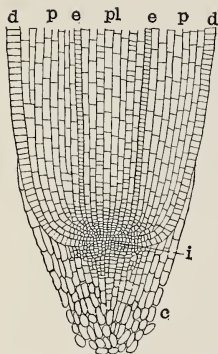


FIG. 47. — GROWING POINT OF ROOT OF INDIAN CORN.

*d, d*, cells which will form the epidermis; *p, p*, cells that will form bark; *e, e*, endodermis; *pl*, cells which will form the axis cylinder; *i*, initial group of cells, or growing point proper; *c*, root-cap.

cap, — this group is the growing point; (*d*) study the slight differences in the tissues a short distance back of the growing point. There are four regions: the central cylinder, made up of several rows of cells in the centre (*pl*); the endodermis, (*e*) composed of a single layer on each side which separates the central cylinder from the bark; the cortex, or inner bark, (*e*) of several layers outside the endodermis; and the epidermis, or outer layer of bark on the outer edges (*d*). Make

a drawing of the section. If a series of the cross-sections of the hypocotyl should be made and studied by the pupil beginning near the growing point and going up-

ward, it would be found that these four tissues become more distinctly marked, for at the tip the tissues have not yet assumed their characteristic form. The central cylinder contains the ducts and vessels which convey the sap.

**The Root-cap.** — Note the form of the root-cap shown in the microscopic section drawn in Fig. 47. Growing cells, and especially those which are forming tissue by subdividing, are very delicate and are easily injured. The



cells forming the root-cap are older and tougher and are suited for pushing aside the soil that the root may penetrate it.

**Region of most Rapid Growth.**—The roots of a seedling bean may be marked at equal distances by waterproof ink or by bits of black thread tied moderately tight. The seedling is then replanted and left undisturbed for two days. When it is dug up, the region of most

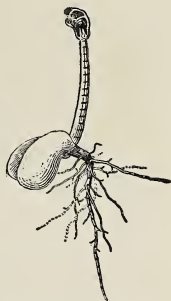


FIG. 48. — THE MARKING OF THE STEM AND ROOT.

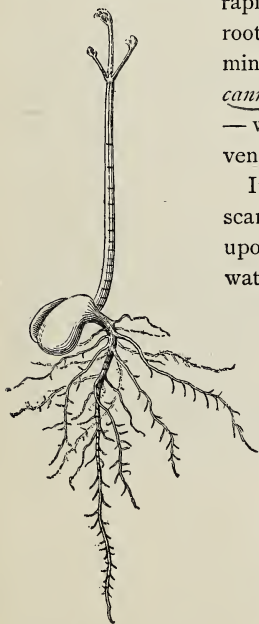


FIG. 49. — THE RESULT.

rapid growth in the root can be determined. Give a reason why a root cannot elongate throughout its length, — whether there is anything to prevent a young root from doing so.

In Fig. 48 is shown a germinating scarlet runner bean with a short root upon which are marks made with waterproof ink; and the same root (Fig. 49) is shown after it has grown longer. Which part of it did not lengthen at all? Which part lengthened slightly? Where is the region of most rapid growth?

**Geotropism.** — Roots turn toward the earth, even if the seed is planted with the micropyle up. This phenomenon is called **positive geotropism**. Stems grow away from the earth. This is negative geotropism.

SUGGESTIONS (Chaps. VII and VIII). — 25. Tests for food. Examine a number of roots, including several fleshy roots, for the presence of food material, making the tests used on seeds. 26. Study of root-hairs. Carefully germinate radish, turnip, cabbage, or other seed, so that no delicate parts of the root will be injured. For this purpose, place a few seeds in packing-moss or in the folds of thick cloth or of blotting paper, being careful to keep them moist and warm. In a few days the seed has germinated, and the root has grown an inch or two long. Notice that, except at a distance of about a quarter of an inch behind the tip, the root is covered with minute hairs (Fig. 44). They are actually hairs; that is, root-hairs. Touch them and they collapse, they are so delicate. Dip one of the plants in water, and when removed the hairs are not to be seen. The water mats them together along the root and they are no longer evident. Root-hairs are usually destroyed when a plant is pulled out of the soil, be it done ever so carefully. They cling to the minute particles of soil (Fig. 46). The hairs show best against a dark background. 27. On some of the blotting papers, sprinkle sand; observe how the root-hairs cling to the grains. Observe how they are flattened when they come in contact with grains of sand. 28. Root

hold of plant. The pupil should also study the root hold. Let him carefully pull up a plant. If a plant grow alongside a fence or other rigid object, he may test the root hold by securing a string to the plant, letting the string hang over the fence, and then adding weights to the string. Will a stake of similar size to the plant and extending no deeper in the ground have such firm hold on the soil? What holds the ball of earth in Fig. 50?



FIG. 50.—THE GRASP OF A PLANT ON THE PARTICLES OF EARTH. A grass plant pulled in a garden.

29. Roots exert pressure. Place a strong bulb of hyacinth or daffodil on firm-packed earth in a pot; cover the bulb nearly to the top with loose earth; place in a cool cellar; after some days

or weeks, note that the bulb has been raised out of the earth by the forming roots. All roots exert pressure on the soil as they grow. Explain. **30. Response of roots and stems to the force of gravity, or geotropism.** Plant a fast-growing seedling in a pot so that the plumule extends through the drain hole and suspend the pot with mouth up (*i.e.* in the usual position). Or use a pot in which a plant is already growing, cover with cloth or wire gauze to prevent the soil from falling, and suspend the pot in an inverted position (Fig. 51). Notice the behaviour of the stem, and after a few days remove the soil and observe the position of the root. **31.** If a pot is laid on one side, and changed every two days and laid on its opposite side, the effect on the root and stem will be interesting. **32.** If a fleshy root is planted wrong end up, what is the result? Try it with pieces of horse-radish root. **33.** By planting radishes on a slowly revolving wheel the effect of gravity may be neutralized. **34. Region of root most sensitive to gravity.** Lay on its side a pot containing a growing plant. After it has grown a few days, wash away the earth surrounding the roots. Which turned downward most decidedly, the tip of root or the upper part? **35. Soil texture.** Carefully turn up soil in a rich garden or field so that you have unbroken lumps as large as a hen's egg. Then break these lumps apart carefully



FIG. 51.—  
PLANT GROW-  
ING IN IN-  
VERTED POT.



FIG. 52.—HOLES IN SOIL MADE BY ROOTS, now decayed. Somewhat magnified.

with the fingers and determine whether there are any traces or remains of roots (Fig. 52). Are there any pores, holes, or channels made by roots? Are the roots in them still living? **36.** Compare another lump from a clay bank or pile where no plants have been growing. Is there any differ-

ence in texture? **37.** Grind up this clay lump very fine, put it in a saucer, cover with water, and set in the sun. After a time it will have the appearance shown in the lower saucer in Fig. 43. Compare this with mellow garden soil. In which will plants grow best, even if the plant-food were the same in both? Why? **38. To test the effect of moisture on the plant,** let a plant in a pot or box dry

out till it wilts ; then add water and note the rapidity with which it recovers. Vary the experiment in quantity of water applied. Does the plant call for water sooner when it stands in a sunny window than when in a cool shady place? Prove it. 39. Immerse a potted plant above the rim of the pot in a pail of water and let it remain there. What is the consequence? Why? 40. To test the effect of temperature on roots. Put one pot in a dish of ice water, and another in a dish of warm water, and keep them in a warm room. In a short time notice how stiff and vigorous is the one whose roots are warm, whereas the other may show signs of wilting. 41. The process of osmosis. Chip away the shell from the large end of an egg so as to expose the uninjured membrane beneath for an area about as large as a ten-cent piece. With sealing-wax, chewing-gum, or paste, stick a quill about three inches long to the smaller end of the egg. After the tube is in place, run a hat pin into it so as to pierce both shell and membrane ; or use a short glass tube, first scraping the shell thin with a knife and then boring through it with the tube. Now set the egg upon the mouth of a pickle jar nearly full of water, so that the large end with the exposed membrane is beneath the water. After several hours, observe the tube on top of the egg to see whether the water has forced its way into the egg and increased its volume so that part of its contents are forced up into the tube. If no tube is at hand, see whether the contents are forced through the hole which has been made in the small end of the egg. Explain how the law of osmosis is verified by your result. If the eggshell contained only the membrane, would water rise into it? If there were no water in the bottle, would the egg-white pass down into the bottle? 42. The region of most rapid growth. The pupil should make marks with waterproof ink (as Higgins' ink or indelible marking ink) on any soft growing roots. Place seeds of bean, radish, or cabbage between layers of blotting paper or thick cloth. Keep them damp and warm. When stem and root have grown an inch and a half long each, with waterproof ink mark spaces exactly one-quarter inch apart (Figs. 48, 49). Keep the plantlets moist for a day or two, and it will be found that on the stem some or all of the marks are more than one-quarter inch apart; on the root the marks have not separated. The root has grown beyond the last mark.

## CHAPTER IX

### THE STEM—KINDS AND FORMS; PRUNING

**The Stem System.**—The stem of a plant is the part that bears the buds, leaves, flowers, and fruits. Its office is to hold these parts up to the light and the air; and through its tissues the various food-materials and the life-giving fluids are distributed to the growing and working parts.

The entire mass or fabric of stems of any plant is called its **stem system**. It comprises the trunk, branches, and twigs, but not the stalks of leaves and flowers that die and fall away. The stem system may be herbaceous or woody, annual, biennial, or perennial; and it may assume many sizes and shapes.

**Stems are of Many Forms.**—The general way in which a plant grows is called its habit. The habit is the appearance or general form. Its habit may be open or loose, dense, straight, crooked, compact, straggling, climbing, erect, weak, strong, and the like. The roots and the leaves are the important functional or working parts; the stem merely connects them, and its form is exceedingly variable.

**Kinds of Stems.**—The stem may be so short as to be scarcely distinguishable. In such cases the crown of the plant—that part just at the surface of the ground—bears the leaves and the flowers; but this crown is really a very short stem. The dandelion, Fig. 33, is an example. Such plants are often said to be stemless, however, in order to distinguish them from plants that have long or conspic-



uous stems. These so-called stemless plants die to the ground every year.

Stems are erect when they grow straight up (Figs. 53, 54). They are trailing when they run along on the ground,



FIG. 53. — STRICT SIMPLE  
STEM OF MULLEIN.



FIG. 54. — STRICT UPRIGHT STEM  
OF NARROW-LEAVED DOCK.

as melon, wild morning-glory (Fig. 55). They are creeping when they run on the ground and take root at places,



FIG. 55. — TRAILING STEM OF WILD MORNING GLORY (*Convolvulus arvensis*).

as the strawberry. They are decumbent when they lop over to the ground. They are ascending when they lie mostly or in part on the ground but stand more or less upright at their ends; example, a tomato. They are

climbing when they cling to other objects for support (Figs. 36, 56).

Trees in which the main trunk or the "leader" continues to grow from its tip are said to be excurrent in growth. *The branches are borne along the sides of the trunk*, as in common pines (Fig. 57) and spruces. Excurrent means *running out* or *running up*.

Trees in which the main trunk does not continue are said to be deliquescent. *The branches arise from one common point or from each other*. The stem is lost in the branches. The apple tree, plum (Fig. 58), maple, elm, oak, China tree, are familiar examples. Deliquescent means *dissolving* or *melting away*.

Each kind of plant has its own peculiar habit or direction of growth. Spruces always grow to a single stem or trunk, pear



FIG. 56.—A CLIMBING PLANT (a twiner).



FIG. 57.—EXCURRENT TRUNK. A pine.



FIG. 58.—DELIQUESCENT TRUNK OF PLUM TREE.



trees are always deliquescent, morning-glories are always trailing or climbing, strawberries are always creeping. We do not know why each plant has its own habit, but the habit is in some way associated with the plant's genealogy or with the way in which it has been obliged to live.

The stem may be **simple** or **branched**. A simple stem usually grows from the terminal bud, and side branches either do not start, or, if they start, they soon perish. Mulleins (Fig. 53) are usually simple. So are palms.

Branched stems may be of very different habit and shape. Some stem systems are narrow and erect; these are said to be strict (Fig. 54). Others are diffuse, open, branchy, twiggy.

**Nodes and Internodes.**—The parts of the stem at which buds grow are called nodes or joints and the spaces between the buds are internodes. The stem at nodes is usually enlarged, and the pith is usually interrupted. The distance between the nodes is influenced by the vigour of the plant: how?



FIG. 59. — RHIZOME OR ROOTSTOCK.

**Stems vs. Roots.**—Roots sometimes grow above ground (Chap. VII); so, also, stems sometimes grow underground, and they are then known as subterranean stems, rhizomes, or rootstocks (Fig. 59).

Stems normally bear leaves and buds, and thereby are they distinguished from roots; usually, also, they contain a pith. The leaves, however, may be reduced to mere scales, and the buds beneath them may be scarcely visible.

Thus the "eyes" on a white potato are cavities with a bud or buds at the bottom (Fig. 60). Sweet potatoes have no evident "eyes" when first dug, (but they may develop adventitious buds before the next growing-season). The white potato is a stem: the sweet potato is probably a root.

**How Stems elongate.** — Roots elongate by growing near the tip. Stems elongate by growing more or less throughout the young or soft part or "between joints" (Figs. 48, 49). But any part

of the stem soon reaches a limit beyond which it cannot grow, or becomes "fixed"; and the new parts beyond elongate until they, too, become rigid. When a part of the stem once becomes fixed or hard, it never increases in length: that is, the trunk or woody parts never grow longer or higher; branches do not become farther apart or higher from the ground.

**Stems are modified in form** by the particular or incidental conditions under which they grow. The struggle for light is the chief factor in determining the shape and the direction of any limb (Chap. II). This is well illustrated in any tree or bush that grows against a building or on the margin of a forest (Fig. 4). In a very dense thicket the innermost trees shoot up over the others or they perish. Examine any stem and endeavour to determine why it took its particular form.

The stem is cylindrical, the outer part being bark and the inner part being wood or woody tissue. In the dicotyledonous plants, the bark is usually easily separated from the remainder of the cylinder at some time of the year; in monocotyledonous plants the bark is not free. Growth in thickness takes place inside the covering and not on the very

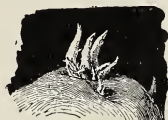


FIG. 60. — SPROUTS ARISING FROM THE BUDS, or eyes, of a potato tuber.

outside of the plant cylinder. It is evident, then, that the covering of *bark must expand in order to allow of the expansion of the woody cylinder within it.* The tissues, therefore, must be under constant pressure or tension. It has been determined that the pressure within a growing trunk is often as much as fifty pounds to the square inch. The lower part of the limb in Fig. 61 shows that the outer layers of bark (which are long since dead, and serve only as protective tissue) have reached the limit of their expanding capacity and have begun to split. The pupil will now be interested in the bark on the body of an old elm tree (Fig. 62); and he should be able to suggest one reason why stems remain cylindrical, and why the old bark becomes marked with furrows, scales, and plates.



FIG. 61.—  
CRACKING  
OF THE  
BARK ON AN  
ELM  
BRANCH.

Most woody plants increase in diameter by the addition of an annual layer or "ring" on the outside of the woody cylinder,

underneath the bark. The monocotyledonous plants comprise very few trees and shrubs in temperate climates (the palms, yuccas, and other tree-like plants are of this class), and they do not increase greatly in diameter and they rarely branch to any extent.

**Bark-bound Trees.**—If, for any reason, the bark should become so dense and strong that the trunk cannot expand, the tree is said to be "bark-bound."

Such condition is not rare in orchard trees that have been neglected. When good tillage is given to such trees, they



FIG. 62.—PIECE OF  
BARK FROM AN  
OLD ELM TRUNK.

may not be able to overcome the rigidity of the old bark, and, therefore, do not respond to the treatment. Sometimes the parts with thinner bark may outgrow in diameter the trunk or the old branches below them. The remedy is to release the tension. This may be done either by softening the bark (by washes of soap or lye), or by separating it. The latter is done by slitting the bark-bound part (in spring), thrusting the point of a knife through the bark to the wood, and then drawing the blade down the entire length of the bark-bound part. The slit is scarcely discernible at first, but it opens with the growth of the tree, filling up with new tissue beneath. Let the pupil consider the ridges which he now and then finds on trees, and determine whether they have any significance—whether the tree has ever been released, or injured by natural agencies.

The Tissue covers the Wounds and "heals" them.

—This is seen in Fig. 63, in which a ring of tissue rolls out over the wound. This ring of healing tissue forms most rapidly and uniformly when the wound is smooth and regular. Observe the healing on broken and splintered limbs; also the difference in rapidity of healing between wounds on strong and weak limbs. There is a difference in the rapidity of the healing process in different kinds of trees. Compare the apple tree and the peach. This tissue may in

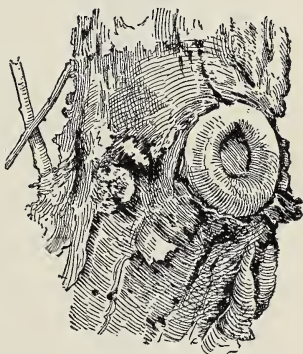


FIG. 63.—PROPER CUTTING OF A BRANCH. The wound will soon be "healed."

turn become bark-bound, and the healing may stop. On large wounds it progresses more rapidly the first few years than it does later. This roll or ring of tissue is called a callus.



FIG. 64. — ERRONEOUS PRUNING.

The callus grows from the living tissue of the stem just about the wound. It cannot cover long dead stubs or very rough broken branches (Fig. 64). Therefore, in pruning the branches should be cut close to the trunk and made even and smooth; all long stubs must be avoided. The seat of the wound should be close to the living part of the trunk, for the

stub of the limb that is severed has no further power in itself of making healing tissue. The end of the remaining stub is merely covered over by the callus, and usually remains a dead piece of wood sealed inside the trunk (Fig. 65). If wounds do not heal over speedily, germs and fungi obtain foothold in the dying wood and rot sets in. Hollow trees are those in which the decay-fungi have progressed into the inner wood of the trunk; they have been infected (Fig. 66).



FIG. 65. — KNOT IN A HEMLOCK LOG.

Large wounds should be protected with a covering of paint, melted wax, or other adhesive and lasting material,





FIG. 66.—A KNOT HOLE, and the beginning of a hollow trunk.

to keep out the germs and fungi. A covering of sheet iron or tin may keep out the rain, but it will not exclude the germs of decay; in fact, it may provide the very moist conditions that such germs need for their growth. Deep holes in trees should be treated by having all the decayed parts removed down to the clean wood, the surfaces painted or otherwise sterilized, and the hole filled with wax or cement.

Stems and roots are living, and they should not be wounded or mutilated unnecessarily. Horses should never be hitched to trees. Supervision should be exercised over persons who run telephone, telegraph, and electric light wires, to see that they do not mutilate trees. Electric light wires and trolley wires, when carelessly strung or improperly insulated, may kill trees (Fig. 67).

SUGGESTIONS.—Forms of stems.

43. Are the trunks of trees ever perfectly cylindrical? If not, what may cause the irregularities? Do trunks often grow more on one side than the other?

44. Slit a rapidly growing limb, in spring, with a knife blade, and watch the result during the season. 45. Examine the woodpile, and observe the variations in thickness of the annual rings, and especially of the same ring at different places in the circumference. Cross-sections of

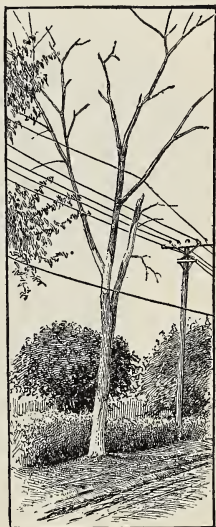


FIG. 67.—ELM TREE KILLED BY A DIRECT CURRENT FROM AN ELECTRIC RAILROAD SYSTEM.

horizontal branches are interesting in this connection. 46. Note the enlargement at the base of a branch, and determine whether this enlargement or bulge is larger on long, horizontal limbs than on upright ones. Why does this bulge develop? Does it serve as a brace to the limb, and is it developed as the result of constant strain? 47. *Strength of stems.* The pupil should observe the fact that a stem has wonderful strength. Compare the proportionate height, diameter, and weight of a grass stem with those of the slenderest tower or steeple. Which has the greater strength? Which the greater height? Which will withstand the most wind? Note that the grass stem will regain its position even if its top is bent to the ground. Note how plants are weighted down after a heavy rain and how they recover themselves. 48. Split a corn-stalk and observe how the joints are tied together and braced with fibres. Are there similar fibres in stems of pigweed, cotton, sunflower, hollyhock?

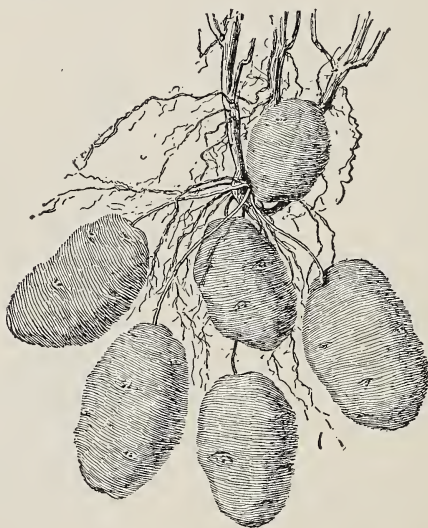


FIG. 68.—POTATO. What are roots, and what stems? Has the plant more than one kind of stem? more than two kinds? Explain.



## CHAPTER X

### THE STEM—ITS GENERAL STRUCTURE

THERE are two main types of stem structure in flowering plants, the differences being based on the arrangement of bundles or strands of tissue. These types are endogenous and exogenous (page 20). It will require patient laboratory work to understand what these types and structures are.

**Endogenous, or Monocotyledonous Stems.** — Examples of endogenous stems are all the grasses, cane-brake, sugarcane, smilax or green-brier, palms, banana, canna, bamboo, lilies, yucca, asparagus, all the cereal grains. For our study, a cornstalk may be used as a type.

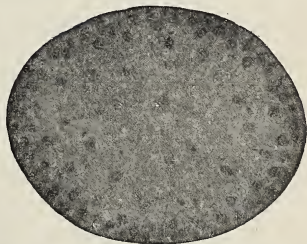


FIG. 69. — CROSS-SECTION OF CORNSTALK, showing the scattered fibro-vascular bundles. Slightly enlarged.

A piece of *cornstalk*, either green or dead, should be in the hand of each pupil while studying this lesson. Fig. 69 will also be of use. Is there a swelling at the nodes? Which part of the internode comes nearest to being perfectly round? There is a grooved channel running along one side of the internode: how is it placed with reference to the leaf? with reference to the groove in the internode below it? What do you find in each groove at its lower end? (In a dried stalk only traces of this are usually seen.) Does any bud on a cornstalk besides the one at

the top ever develop? Where do suckers come from? Where does the ear grow?

Cut a cross-section of the stalk between the nodes (Fig. 69). Does it have a distinct bark? The interior consists of soft "pith" and tough woody parts. The wood is found in strands or fibres. Which is more abundant? Do the fibres have any definite arrangement? Which strands are largest? Smallest? The firm smooth rind (which cannot properly be called a bark) consists of small wood strands packed closely together. Grass stems are hollow cylinders; and the cornstalk, because of the lightness of its contents, is also practically a cylinder. Stems of this kind are admirably adapted for providing a strong support to leaves and fruit. This is in accordance with the well-known law that a hollow cylinder is much stronger than a solid



FIG. 70. — DIAGRAM TO SHOW THE COURSE OF FIBRO-VASCULAR BUNDLES IN MONOCOTYLEDONS.

cylinder of the same weight of material. Cut a thin slice of the inner soft part and hold it up to the light. Can you make out a number of tiny compartments or cells? These cells consist of a tissue called parenchyma, the tissue from which when young all the other tissues arise and differentiate. The numerous walls of these cells may serve to brace the outer wall of the cylinder; but their chief function in the young stalk is to give origin to other cells. When alive they are filled with cell sap and protoplasm.

Trace the *woody strands* through the nodes. Do they ascend vertically? Do they curve toward the rind at certain places? Compare their course with the strands shown in Fig. 70. The woody strands consist chiefly of tough fibrous cells that give rigidity

and strength to the plant, and of long tubular interrupted canals that serve to convey sap upward from the root and to convey food downward from the leaves to the stem and the roots.

Monocotyledons, as shown by fossils, existed before dicotyledons appeared, and it is thought that the latter were developed from ancestors of the former. It will be interesting to trace the relationship in stem structure. It will first be necessary to learn something of the structure of the wood strand.

**Wood Strand in Monocotyledons and Dicotyledons.**—Each wood strand (or fibro-vascular bundle) consists of two parts—the bast and the wood proper. The wood is on the side of the strand toward the centre of the stem and contains large tubular canals that take the watery sap upward from the roots. The bast is on the side toward the bark,



FIG. 71.—DIAGRAM OF WOOD STRANDS OR FIBRO-VASCULAR BUNDLES IN A ROOT, showing the wood (x) and bast (p) separated.



FIG. 72.—PART OF CROSS-SECTION OF ROOT-STOCK OF ASPARAGUS, showing a few fibro-vascular bundles. An endogenous stem.

and contains fine tubes through which diffuses the dense sap containing digested food from the leaves. In the root (Fig. 71) the bast and the wood are separate, so that there are two kinds of strands.

In monocotyledons, as already said, the strands (or bundles) are usually scattered in the stem with no definite arrangement (Figs. 72, 73). In dicotyledons the strands, or bundles, are arranged in a



FIG. 73. — THE SCATTERED BUNDLES OR STRANDS, in monocotyledons at *a*, and the bundles in a circle in dicotyledons at *b*.

the multiplication continues, in tough plants, until the bundles touch (Fig. 74, right). The inner parts thus form a ring of wood and the outer parts form the inner bark or bast. A new ring of wood or bast is formed on stems of dicotyledons each year, and the age of a cut stem is easily determined.

When cross-sections of monocotyledonous and dicotyledonous bundles are examined under the microscope, it is readily seen

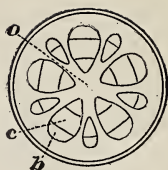
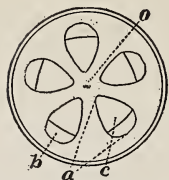


FIG. 74. — DICOTYLEDONOUS STEM OF ONE YEAR AT LEFT WITH FIVE BUNDLES, and a two-year stem at right.

*o*, the pith; *c*, the wood part; *b*, the bast part; *a*, one year's growth.

ring. As the dicotyledonous seed germinates, five bundles are usually formed in its hypocotyl (Fig. 74); soon five more are interposed between them, and the multi-

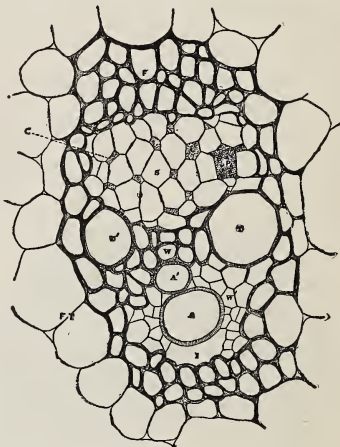


FIG. 75. — FIBRO-VASCULAR BUNDLE OF INDIAN CORN, much magnified.

*A*, annular vessel; *A'*, annular or spiral vessel; *TT'*, thick-walled vessels; *W*, tracheids or woody tissue; *F*, sheath of fibrous tissue surrounding the bundle; *FT*, fundamental tissue or pith; *S*, sieve tissue; *P*, sieve plate; *C*, companion cell; *I*, intercellular space, formed by tearing down of adjacent cells; *W'*, wood parenchyma.

why dicotyledonous bundles form rings of wood and monocotyledonous cannot (Figs. 75 and 76). The dicotyledonous bundle (Fig. 76) has, running across it, a layer of brick-shaped cells called **cambium**, which cells are a specialized form of the parenchyma cells and retain the power of

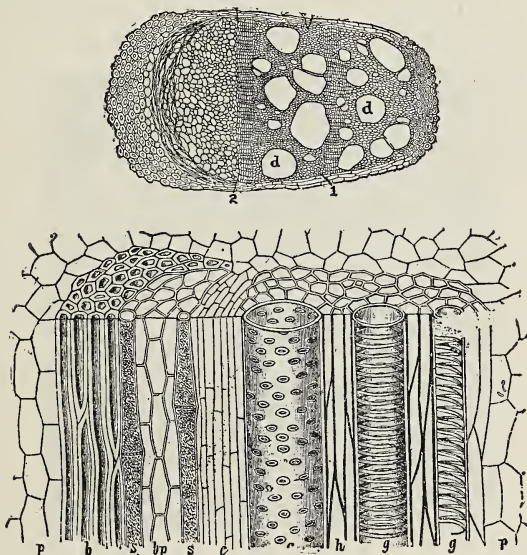


FIG. 76.—THE DICOTYLEDONOUS BUNDLE OR WOOD STRAND. Upper figure is of moonseed :

*c*, cambium ; *d*, ducts ; *1*, end of first year's growth ; *2*, end of second year's growth ; bast part at left and wood part at right. Lower figure (from Wettstein) is sunflower : *h*, wood-cells ; *g*, vessels ; *c*, cambium ; *p*, fundamental tissue or parenchyma ; *b*, bast ; *bp*, bast parenchyma ; *s*, sieve-tubes.

growing and multiplying. The bundles containing cambium are called open bundles. There is no cambium in monocotyledonous bundles (Fig. 75) and the bundles are called closed bundles. Monocotyledonous stems soon cease to grow in diameter. The stem of a palm tree is almost



as large at the top as at the base. As dicotyledonous plants grow, the stems become thicker each year, for the delicate active cambium layer forms new cells from early spring until midsummer or autumn, adding to the wood within and to the bark without. As the growth in spring is very rapid, the first wood-cells formed are much larger than the last wood-cells formed by the slow growth of the



FIG. 77.—WHITE PINE STEM, 5 years old. The outermost layer is bark.

late season, and the spring wood is less dense and of a lighter colour than the summer wood; hence the time between two years' growth is readily made out (Figs. 77 and 78). Because of the rapid growth of the cambium in spring and its consequent soft walls and fluid contents, the bark of trees "peels" readily at that season.

**Medullary Rays.**—The first year's growth in dicotyledons forms a woody ring which almost incloses the pith, and this is left as a small cylinder which does not grow



larger, even if the tree should live a century. It is not quite inclosed, however, for the narrow layers of soft cells separating the bundles remain between them (Fig. 78), forming radiating lines called medullary rays or pith rays.

**The Several Plant Cells and their Functions.**—In the wood there are some parenchyma cells that have thin walls still, but have lost

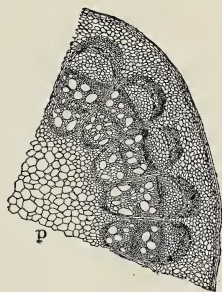


FIG. 78.—ARRANGEMENT OF TISSUES IN TWO-YEAR-OLD STEM OF MOONSEED.

*p*, pith; *f*, parenchyma. The fibro-vascular bundles, or wood strands, are very prominent, with thin medullary rays between.

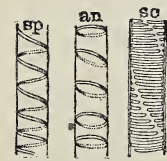


FIG. 79.—MARKINGS IN CELL WALLS OF WOOD FIBRE

*sp*, spiral; *an*, annular; *sc*, scalariform.

the power of division. They are now storage cells.

There are also wood fibres which are thick-walled and rigid (*h*, Fig.

76), and serve to *support* the sap-canals or *wood vessels* (or tracheids) that are formed by the absorption of the end

walls of upright rows of cells; the canals pass from the roots to the twigs and even to ribs of the leaves and serve to transport the root water. They are recognized (Fig. 79) by the peculiar thickening of the wall on the inner surface of the tubes, occurring in the form of spirals. Sometimes the whole wall is thickened except in spots called *pits* (*g*, Fig. 76). These thin spots (Fig. 80) allow the sap to pass to other cells or to neighbouring vessels.

**The cambium**, as we have seen, consists of cells whose function is growth. These

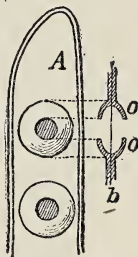


FIG. 80.—PITS IN THE CELL WALL.

Longitudinal section of wall at *b*, showing pit borders at *a*, *a*.

cells are thin-walled and filled with protoplasm. During the growing season they are continually adding to the wood within and the bark with-out; hence the layer moves out-ward as it deposits the new woody layer within.

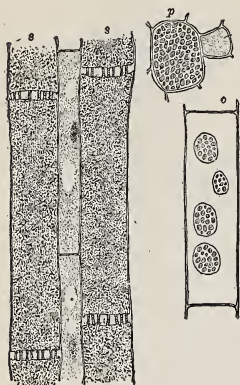


FIG. 81.—SIEVE-TUBES, *s, s*;

*p* shows a top view of a sieve-plate, with a companion cell, *c*, at the side; *o* shows sieve-plates in the side of the cell. In *s*, the protoplasm is shrunken from the walls by reagents.

The bark consists of inner or fibrous bark or new bast (these fibres in flax become linen), the green or middle bark which functions somewhat as the leaves, and the corky or outer bark. The common word “bark” is seen, therefore, not to represent a homogeneous or simple structure, but rather a collection of several kinds of tissue, all separating from the wood beneath by means of cambium. The new bast contains (1) the sieve-tubes (Fig. 81) which transport the

sap containing organic substances, as sugar and proteids, from the leaves to the parts needing it (*s*, Fig. 76). These tubes have been formed like the wood vessels, but they have sieve-plates to allow the dense organic-laden sap to pass with sufficient readiness for purposes of rapid distribution. (2) There are also thick-walled bast fibres (Fig. 82) in the bast that serve for support. (3) There is also some parenchyma in the new bast; it is now in part a storage tissue. Some-



FIG. 82.—THICK-WALLED BAST CELLS.

times the walls of parenchyma cells in the cortex thicken at the corners and form *brace cells* (Fig. 83) (collenchyma) for *support*; sometimes the whole wall is thickened, forming *grit cells* or *stone cells* (Fig.

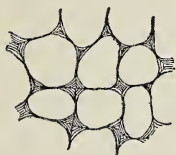


FIG. 83. — COLLEN-  
CHYMA IN WILD  
JEWELWEED OR  
TOUCH-ME-NOT (IM-  
PATIENS).

84; examples in tough parts of pear, or in stone of fruits). Some parts serve for secretions (milk, rosin, etc.) and are called *latex tubes*.

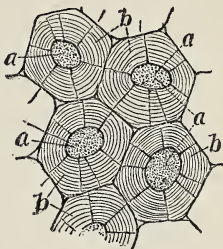


FIG. 84. — GRIT CELLS.

The **outer bark** of old shoots consists of *corky* cells that *protect* from mechanical injury, and that contain a fatty substance (suberin) impermeable to water and of service to *keep in moisture*. There is sometimes a cork cambium (or phellogen) in the bark that serves to extend the bark and keep it from splitting, thus increasing its power to protect.

**Transport of the "Sap."**—We shall soon learn that the common word "sap" does not represent a single or simple substance. We may roughly distinguish two kinds of more or less fluid contents: (1) *the root water*, sometimes called mineral sap, that is taken in by the root, containing its freight of such inorganic substances as potassium, calcium, iron, and the rest; this root water rises, we have found, *in the wood vessels*,—that is, in the young or "sapwood" (p. 96); (2) *the elaborated or organized materials* passing back and forth, especially from the leaves, to build up tissues in all parts of the plant, some of it going down to the roots and root-hairs; this organic material is transported, as we have learned, *in the sieve-tubes of the inner bast*,—that is, in the "inner bark." Removing the bark from a trunk in

a girdle will not stop the upward rise of the root water so long as the wood remains alive ; but it will stop the passage of the elaborated or food-stored materials to parts below and thus starve those parts ; and if the girdle does not heal over by the deposit of new bark, the tree will in time *starve to death*. It will now be seen that the common practice of placing wires or hoops about trees to hold them in position or to prevent branches from falling is irrational, because such wires interpose barriers over which

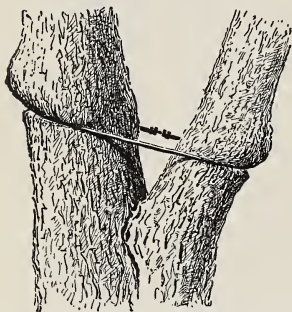


FIG. 85.—THE WRONG WAY TO BRACE A TREE. (See Fig. 118).

the fluids cannot pass ; in time, as the trunk increases in diameter, the wire girdles the tree. It is much better to bolt the parts together by rods extending through the branches (Fig. 85). These bolts should fit very tight in their holes. Why?

**Wood.**—The main stem or trunk, and sometimes the larger branches, are the sources of lumber and timber.

Different kinds of wood have value for their special qualities. The business of raising wood, for all purposes, is known as *forestry*. The forest is to be considered as a crop, and the crop must be harvested, as much as corn or rice is harvested. Man is often able to grow a more productive forest than nature does.

**Resistance to decay** gives value to wood used for shingles (*cypress*, heart of *yellow pine*) and for fence posts (*mulberry*, *cedar*, *post oak*, *bois d'arc*, *mesquite*).

**Hardness and strength** are qualities of great value in building. *Live oak* is used in ships. *Red oak*, *rock maple*,

and *yellow pine* are used for floors. The best flooring is sawn with the straight edges of the annual rings upward; tangential sawn flooring may splinter. *Chestnut* is common in some parts of the country, being used for ceiling and inexpensive finishing and furniture. *Locust* and *bois d'arc* (osage orange) are used for hubs of wheels; *bois d'arc* makes a remarkably durable pavement for streets. *Ebony* is a tropical wood used for flutes, black piano keys, and fancy articles. *Ash* is straight and elastic; it is used for handles for light implements. *Hickory* is very strong as well as elastic, and is superior to ash for handles, spokes, and other uses where strength is wanted. *Hickory* is never sawn into lumber, but is split or turned. The "second growth," which sprouts from stumps, is most useful, as it splits readily. Fast-growing hickory in rich land is most valuable. The supply of useful hickory is being rapidly exhausted.

**Softness is often important.** *White pine* and *sweet gum* because of their softness and lightness are useful in box-making. "*Georgia*" or *southern pine* is harder and stronger than white pine; it is much used for floors, ceilings, and some kinds of cabinet work. *White pine* is used for window-sash, doors, and moulding, and cheaper grades are used for flooring. *Hemlock* is the prevailing lumber in the east for the framework and clapboarding of buildings. *Redwood* and *Douglas spruce* are common building materials on the Pacific coast. *Cypress* is soft and resists decay and is superior to white pine for sash, doors, and posts on the outside of houses. *Cedar* is readily carved and has a unique use in the making of chests for clothes, as its odour repels moths and other insects. *Willow* is useful for baskets and light furniture. *Basswood* or *linden* is used for light ceiling and sometimes for cheap floors. *Whitewood*

(incorrectly called poplar) is employed for wagon bodies and often for house finishing. It often resembles curly maple.

**Beauty of grain and polish** gives wood value for furniture, pianos, and the like. *Mahogany* and *white oak* are most beautiful, although red oak is also used. Oak logs which are first quartered and then sawn radially expose the beautiful silver grain (medullary rays).

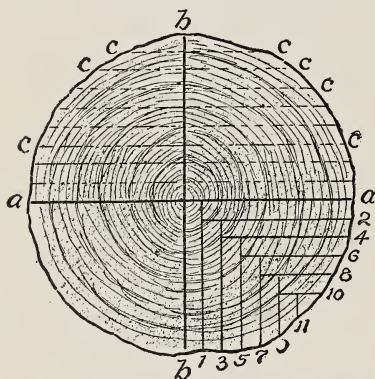


FIG. 86. — THE MAKING OF ORDINARY BOARDS, AND ONE WAY OF MAKING "QUARTERED" BOARDS.

*mode of quartering.*

The log is quartered on the lines *a, a, b, b*; then succeeding boards are cut from each quarter at 1, 2, 3, etc. The nearer the heart the better the "grain": why? Ordinary boards are sawn tangentially, as *c, c*. *Curly pine*, *curly walnut*, and *bird's-eye maple* are woods that owe their

beauty of grain to wavy lines or buried knots. A mere stump of curly walnut is worth several hundred dollars. Such wood is sliced very thin for veneering and glued over other woods in making pianos and furniture. If the cause of wavy grain could be found out and such wood grown at will, the discovery would be very useful. *Maple* is much used for furniture. *Birch* may be coloured so as very closely to represent mahogany, and it is useful for desks.

**Special Products of Trees.**—Cork from the bark of the cork oak in Spain, latex from the rubber, and sap from the



sugar-maple trees, turpentine from pine, tannin from oak bark, Peruvian bark from cinchona, are all useful products.

SUGGESTIONS. — *Parts of a root and stem through which liquids rise.* 49. Pull up a small plant with abundant leaves, cut off the root so as to leave two inches or more on the plant (or cut a leafy shoot of squash or other strong-growing coarse plant), and stand it in a bottle with a little water at the bottom which has been coloured with red ink (eosine). After three hours examine the root; make cross sections at several places. Has the water coloured the axis cylinder? The cortex? What is your conclusion? Stand some cut flowers or a leafy plant with cut stem in the same solution and examine as before: conclusion? 50. Girdle a twig of a rapidly growing bush (as willow) in early spring when growth begins (*a*) by very carefully removing only the bark, and (*b*) by cutting away also the sapwood. Under which condition do the leaves wilt? Why? 51. Stand twigs of willow in water; after roots have formed under the water, girdle the twig (in the two ways) above the roots. What happens to the roots, and why? 52. Observe the swellings on trees that have been girdled or very badly injured by wires or otherwise: where are these swellings, and why? 53. *Kinds of wood.* Let each pupil determine the kind of wood in the desk, the floor, the door and window casings, the doors themselves, the sash, the shingles, the fence, and in the small implements and furniture in the room; also what is the cheapest and the most expensive lumber in the community. 54. How many kinds of wood does the pupil know, and what are their chief uses?

NOTE TO TEACHER. — The work in this chapter is intended to be mainly descriptive, for the purpose of giving the pupil a rational conception of the main vital processes associated with the stem, in such a way that he may translate it into his daily thought. It is not intended to give advice for the use of the compound microscope. If the pupil is led to make a careful study of the text, drawings, and photographs on the preceding and the following pages, he will obtain some of the benefit of studying microscope sections without being forced to spend time in mastering microscope technique. If the school is equipped with compound microscopes, a teacher is probably chosen who has the necessary skill to manipulate them and the knowledge of anatomy and physiology that goes naturally with such work; and it would be useless to give instruction in such work in a text of this kind. The writer is of the opinion that the introduction of the compound microscope into first courses in botany has been productive of harm. Good and vital teaching demands first that the pupil have a normal,

direct, and natural relation to his subject, as he commonly meets it, that the obvious and significant features of the plant-world be explained to him and be made a means of training him. The beginning pupil cannot be expected to know the fundamental physiological processes, nor is it necessary that these processes should be known in order to have a point of view and trained intelligence on the things that one customarily sees. Many a pupil has had a so-called laboratory course in botany without having arrived at any real conception of what plants mean, or without having had his mind opened to any real sympathetic touch with his environment. Even if one's knowledge be not deep or extensive, it may still be accurate as far as it goes, and his outlook on the subject may be rational.

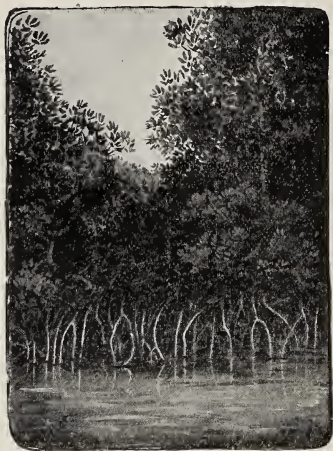


FIG. 87. — THE MANY-STEMMED THICKETS OF MANGROVE OF SOUTHERNMOST SEACOASTS, many of the trunks being formed of aerial roots.

## CHAPTER XI

### LEAVES—FORM AND POSITION

LEAVES may be studied from four points of view, — with reference to (1) their *kinds* and *shapes*; (2) their *position*, or *arrangement* on the plant; (3) their *anatomy*, or *structure*;



FIG. 88. — A SIMPLE NETTED-VEINED LEAF.

(4) their *function*, or the work they perform. This chapter is concerned with the first two categories.



FIG. 90. — COMPOUND OR BRANCHED LEAF OF BRAKE (a common fern).



FIG. 89. — A SIMPLE PARALLEL-VEINED LEAF.

**Kinds.** — Leaves are **simple** or unbranched (Figs. 88, 89), and **compound** or branched (Fig. 90).

The method of compounding or branching follows the mode of veining. The veining, or **venation**, is of two general kinds. In some plants the main veins diverge, and there is a conspicuous network of smaller veins; such leaves are **netted-veined**. They are characteristic of the dicotyledons. In other plants the main veins are parallel, or nearly so, and there is no conspicuous network; these are **parallel-veined** leaves (Figs. 89, 102). These leaves are the rule in monocotyledonous plants. The venation of netted-veined leaves is **pinnate** or feather-like when the veins arise from the side of a continuous midrib (Fig. 91); **palmate** or **digitate** (hand-like) when the veins arise from the apex of the petiole (Figs. 88, 92). If leaves were divided between the main veins, the former would be pinnately and the latter digitately compound.

It is customary to speak of a leaf as compound only when the parts or branches are completely separate blades,



FIG. 91. — COMPLETE LEAVES OF WILLOW.



FIG. 92. — DIGITATE-VEINED PELATE LEAF OF NASTURTIUM.



FIG. 93. — PINNATELY COMPOUND LEAF OF ASH.

as when the division extends to the midrib (Figs. 90, 93, 94, 95). The parts or branches are known as **leaflets**.

Sometimes the leaflets themselves are compound, and the whole leaf is then said to be **bi-compound** or **twice-com-**



FIG. 94.—DIGITATELY COMPOUND LEAF OF RASPBERRY.



FIG. 95.—POISON IVY. LEAF AND FRUIT.

**pound** (Fig. 90). Some leaves are three-compound, four-compound, or five-compound. **Decompound** is a general term to express any degree of compounding beyond twice-compound.

Leaves that are not divided as far as to the midrib are said to be:

**lobed**, if the openings or sinuses are not more than half the depth of the blade (Fig. 96);

**cleft**, if the sinuses are deeper than the middle;



FIG. 96.—LOBED LEAF OF SUGAR MAPLE.



FIG. 97.—DIGITATELY PARTED LEAVES OF BEGONIA.

**parted**, if the sinuses reach two thirds or more to the midrib (Fig. 97);

**divided**, if the sinuses reach nearly or quite to the midrib.

The parts are called **lobes**, **divisions**, or **segments**, rather than leaflets. The leaf may be pinnately or digitately

lobed, parted, cleft, or divided. A pinnately parted or cleft leaf is sometimes said to be **pinnatifid**.

Leaves may have one or all of three parts — **blade**, or expanded part; **petiole**, or stalk; **stipules**, or appendages

at the base of the petiole. A leaf that has all three of these parts is said to be **complete** (Figs. 91, 106). The stipules are often green and leaflike and perform the function of foliage as in the



FIG. 98.—OBLONG-OVATE SESSILE LEAVES OF TEA.

pea and the Japanese quince (the latter common in yards).

Leaves and leaflets that have no stalks are said to be **sessile** (Figs. 98, 103), *i.e.* sitting. Find several examples.



The same is said of flowers and fruits. The blade of a sessile leaf may partly or wholly surround the stem, when it is said to be **clasping**. Examples: aster (Fig. 99), corn. In some cases the leaf runs down the stem, forming a wing; such leaves are said to be **decurrent** (Fig. 100). When opposite sessile leaves are joined by their bases, they are said to be **connate** (Fig. 101).



FIG. 99.—CLASP-  
ING LEAF OF A  
WILD ASTER.

Leaflets may have one or all of these

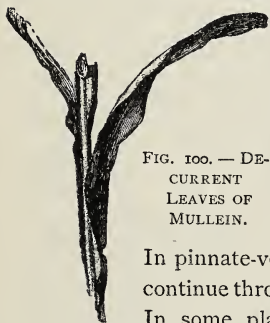


FIG. 100.—DE-  
CURRENT  
LEAVES OF  
MULLEIN.

three parts, but the stalks of leaflets are called **petiolules** and the stipules of leaflets are called **stipels**. The leaf of the garden bean has leaflets, petiolules, and stipels.

The blade is usually attached to the petiole by *its lower edge*.

In pinnate-veined leaves, the petiole seems to continue through the leaf as a **midrib** (Fig. 91).

In some plants, however, the petiole joins the blade inside or beyond the margin (Fig. 92). Such leaves are said to be **peltate** or shield-shaped. This mode of attachment is particularly common in floating leaves (*e.g.* the water lilies). Peltate leaves are usually digitate-veined.

**How to Tell a Leaf.**—It is often difficult to distinguish compound leaves from leafy branches, and leaflets



FIG. 101.—TWO PAIRS OF CONNATE  
LEAVES OF HONEYSUCKLE.

from leaves. As a rule leaves can be distinguished by the following tests: (1) Leaves are *temporary structures*, sooner or later falling. (2) Usually *buds are borne in their axils*. (3) Leaves are usually *borne at joints or nodes*. (4) They arise on wood of the *current year's growth*. (5) They have a more or less *definite arrangement*. When leaves fall, the twig that bore them remains; when leaflets fall, the main petiole or stalk that bore them also falls.

**Shapes.**—Leaves and leaflets are infinitely variable in shape. Names have been given to some of the more definite or regular shapes. These names are a part of the language of botany. The names represent ideal or typical shapes; there are no two leaves alike and very few that perfectly conform to the definitions. The shapes are likened to those of familiar objects or of geometrical figures. Some of the commoner shapes are as follows (name original examples in each class):



FIG. 102.—  
LINEAR-  
ACUMINATE  
LEAF OF  
GRASS.

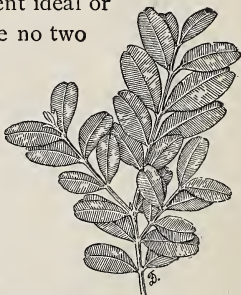


FIG. 103.—SHORT-OBLONG  
LEAVES OF BOX.

**Linear**, several times longer than broad, with the sides nearly or quite parallel. Spruces and most grasses are examples (Fig. 102). In linear leaves, the main veins are usually parallel to the midrib.

**Oblong**, twice or thrice as long as broad, with the sides parallel for most of their length. Fig. 103 shows the short-oblong leaves of the box, a plant that is used for permanent edgings in gardens.

**Elliptic** differs from the oblong in having the sides gradually tapering to either end from the middle. The European beech (Fig. 104) has elliptic leaves. (This tree is often planted in this country.)

**Lanceolate**, four to six times longer than broad, widest below the middle, and tapering to either end. Some of the narrow-leaved willows are examples. Most of the willows and the peach have oblong-lanceolate leaves.

**Spatulate**, a narrow leaf that is broadest toward the apex. The top is usually rounded.



FIG. 104. —  
ELLIPTIC LEAF  
OF PURPLE  
BEECH.

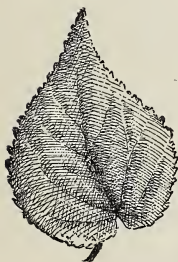


FIG. 105. — OVATE  
SERRATE LEAF OF  
HIBISCUS.



FIG. 106. — LEAF OF APPLE, showing blade,  
petiole, and small narrow stipules.

**Ovate**, shaped somewhat like the longitudinal section of an egg: about twice as long as broad, tapering from near the base to the apex. This is one of the commonest leaf forms (Figs. 105, 106).

**Obovate**, ovate inverted,—the wide part towards the apex.

Leaves of mullein and leaflets of horse-chestnut and false indigo are obovate. This form is commonest in leaflets of digitate leaves: why?

**Reniform**, kidney-shaped. This form is sometimes seen in wild plants, particularly in root-leaves. Leaves of wild ginger are nearly reniform.

**Orbicular**, circular in general outline. Very few leaves are perfectly circular, but there are many that are nearer circular than of any other shape. (Fig. 107).



FIG. 107.—ORBICULAR  
LOBED LEAVES.



FIG. 108.—TRUNCATE  
LEAF OF TULIP TREE.

The shape of many leaves is described in combinations of these terms: as **ovate-lanceolate**, **lanceolate-oblong**.

The shape of the base and the apex of the leaf or leaflet is often characteristic. The base may be **rounded** (Fig. 104), **tapering** (Fig. 93), **cordate** or heart-shaped (Fig. 105), **truncate** or squared as if cut off. The apex may be **blunt** or **obtuse**, **acute** or sharp, **acuminate** or long-pointed, **truncate** (Fig. 108). Name examples.

The shape of the margin is also characteristic of each kind of leaf. The margin is **entire** when it is not indented or cut in any way (Figs. 99, 103). When not

entire, it may be **undulate** or wavy (Fig. 92), **serrate** or saw-toothed (Fig. 105), **dentate** or more coarsely notched (Fig. 95), **crenate** or round-toothed, **lobed**, and the like. Give examples.

Leaves on the same plant often differ greatly in form. Observe the different shapes of leaves on the young growths of mulberries (Fig. 2) and wild grapes; also on vigorous squash and pumpkin vines. In some cases there may be simple and compound leaves on the same plant. This is marked in the so-called Boston ivy or ampelopsis (Fig. 109), a vine that is used to cover brick and stone buildings. Different degrees of compounding, even in the same leaf, may often be found in honey locust. Remarkable differences in forms are seen by comparing seed-leaves with mature leaves of any plant (Fig. 30).



FIG. 109.—DIFFERENT FORMS OF LEAVES FROM ONE PLANT OF AMPELOPSIS.

**The Leaf and its Environment.**—The form and shape of the leaf often have direct relation to the *place in which the leaf grows*. *Floating leaves* are usually expanded and flat, and the petiole varies in length with the depth of the water. *Submerged leaves* are usually linear or thread-like, or are cut into very narrow divisions: thereby more surface is exposed, and possibly the leaves are less injured by moving water. Compare the sizes of the leaves on the ends of branches with those at the base of the

branches or in the interior of the tree top. In dense foliage masses, the petioles of the lowermost or undermost leaves *tend to elongate*—to push the leaf to the light.

On the approach of winter the leaf usually ceases to work, and dies. It may drop, when it is said to be **deciduous**; or it may remain on the plant, when it is said to be **persistent**. If persistent leaves remain green during the winter, the plant is said to be **evergreen**. Give examples in each class. Most leaves fall by breaking off at the lower end of the petiole with a *distinct joint or articulation*. There are many leaves, however, that wither and hang on the plant until torn off by the wind; of such are the leaves of grasses, sedges, lilies, orchids, and other plants of the monocotyledons. Most leaves of this character are parallel-veined.

*Leaves also die and fall from lack of light.* Observe the yellow and weak leaves in a dense tree top or in any thicket. Why do the lower leaves die on house plants? Note the carpet of needles under the pines. All evergreens shed their leaves after a time. Counting back from the tip of a pine or spruce shoot, determine how many years the leaves persist. In some spruces a few leaves may be found on branches ten or more years old.

**Arrangement of Leaves.**—Most leaves have a regular *position or arrangement* on the stem. *This position or direction is determined largely by exposure to sunlight.* In temperate climates they usually hang in such a way that they receive the greatest amount of light. One leaf shades another to the least possible degree. If the plant were placed in a new position with reference to light, the leaves would make an effort to turn their blades.

*When leaves are opposite the pairs usually alternate.* That is, if one pair stands north and south, the next pair



stands east and west. See the box-elder shoot, on the left in Fig. 110. *One pair does not shade the pair beneath.* The leaves are in four vertical ranks.

*There are several kinds of alternate arrangement.* In the elm shoot, in Fig. 110, the third bud is vertically above the first. This is true no matter which bud is taken as the starting point. Draw a thread around the stem until the two buds are joined. Set a pin at each bud. Observe that two buds are passed (not counting the last) and that the thread makes one circuit of the stem. Representing the number of buds by a denominator, and the number of circuits by a numerator, we have the fraction  $\frac{1}{2}$ , which expresses

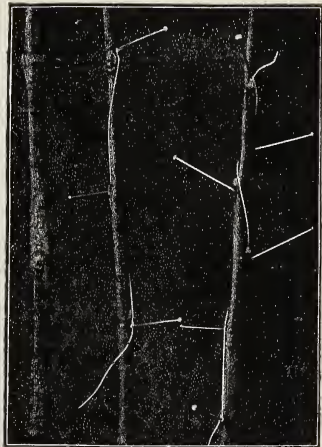


FIG. 110. — PHYLLOTAXY OF BOX ELDER, ELM, APPLE.

*the part of the circle that lies between any two buds.* That is, the buds are one half of 360 degrees apart, or 180 degrees. Looking endwise at the stem, the leaves are seen to be 2-ranked. Note that in the apple shoot (Fig. 110, right) the thread makes two circuits and five buds are passed: *two fifths represents the divergence between the buds.* The leaves are 5-ranked.

*Every plant has its own arrangement of leaves.* For opposite leaves, see maple, box elder, ash, lilac, honeysuckle, mint, fuchsia. For 2-ranked arrangement, see all grasses, Indian corn, basswood, elm. For 3-ranked

arrangement, see all sedges. For 5-ranked (which is one of the commonest), see apple, cherry, pear, peach, plum, poplar, willow. For 8-ranked, see holly, osage orange, some willows. More complicated arrangements occur in bulbs, house leeks, and other condensed plants. The buds or "eyes" on a potato tuber, which is an underground stem

(why?), show a spiral arrangement (Fig. 111).

*The arrangement of leaves on the stem is known as phyllotaxy* (literally, "leaf arrangement"). Make out the phyllotaxy on six different plants nearest the schoolhouse door.

In some plants, several leaves occur at one level, being arranged in a circle around the stem. Such leaves are said to be **verticillate**, or **whorled**. Leaves arranged in this way are usually narrow: why?

Although a definite arrangement of leaves is the rule in most plants, *it is subject to modification*. On shoots that receive the light only from one side or that grow in difficult positions, the arrangement may not be definite. Examine shoots that grow on the under side of dense tree tops or in other partially lighted positions.



FIG. 111. —  
PHYLLOTAXY  
OF THE PO-  
TATO TUBER.  
Work it out  
on a fresh  
long tuber.

**SUGGESTIONS.** — **55.** The pupil should match leaves to determine whether any two are alike. Why? Compare leaves from the same plant in size, shape, colour, form of margin, length of petiole, venation, texture (as to thickness or thinness), stage of maturity, smoothness or hairiness. **56.** Let the pupil take an average leaf from each of the first ten different kinds of plants that he meets and compare them as to the above points (in Exercise 55), and also name the shapes. Determine how the various leaves resemble and differ. **57.** Describe the stipules of rose, apple, fig, willow, violet, pea, or others. **58.** In what part of the world are parallel-veined leaves the more common? **59.** Do

you know of parallel-veined leaves that have lobed or dentate margins? 60. What becomes of dead leaves? 61. Why is there no grass or other undergrowth under pine and spruce trees? 62. Name several leaves that are useful for decorations. Why are they useful? 63. What trees in your vicinity are most esteemed as shade trees? What is the character of their foliage? 64. Why are the internodes so long in water-sprouts and suckers? 65. How do foliage characters in corn or sorghum differ when the plants are grown in rows or broadcast? Why? 66. Why may removal of half the plants increase the yield of cotton or sugar-beets or lettuce? 67. How do leaves curl when they wither? Do different leaves behave differently in this respect? 68. What kinds of leaves do you know to be eaten by insects? By cattle? By horses? What kinds are used for human food? 69. How would you describe the shape of leaf of peach? apple? elm? hackberry? maple? sweet-gum? corn? wheat? cotton? hickory? cowpea? strawberry? chrysanthemum? rose? carnation? 70. Are any of the foregoing leaves compound? How do you describe the shape of a compound leaf? 71. How many sizes of leaves do you find on the bush or tree nearest the schoolroom door? 72. How many colours or shades? 73. How many lengths of petioles? 74. Bring in all the shapes of leaves that you can find.



FIG. 112. — COW-  
PEA. Describe  
the leaves. For  
what is the plant  
used?

## CHAPTER XII

### LEAVES—STRUCTURE OR ANATOMY

BESIDES the framework, or system of veins found in blades of all leaves, there is a soft cellular tissue called **mesophyll**, or **leaf parenchyma**, and an **epidermis** or skin that covers the entire outside part.

**Mesophyll.**—The mesophyll is *not all alike or homogeneous*. The upper layer is composed of elongated cells placed perpendicular to the surface of the leaf. These are called **palisade cells**. These cells are usually filled



FIG. 113.—SECTION OF A LEAF, showing the air spaces.

Breathing-pore or stoma at *a*. The palisade cells which chiefly contain the chlorophyll are at *b*. Epidermal cells at *c*.

with green bodies called **chlorophyll grains**.

The grain contains a great number of chlorophyll drops imbedded in the protoplasm.

Below the palisade cells is the

spongy **parenchyma**, composed of cells more or less spherical in shape, irregularly arranged, and provided with many intercellular air cavities (Fig. 113). In leaves of some plants exposed to strong light there may be more than one layer of palisade cells, as in the India-rubber plant and the oleander. Ivy when grown in bright light will develop two such layers of cells, but in shaded places it may be

found with only one. Such plants as iris and compass plant, which have both surfaces of the leaf equally exposed to sunlight, usually have a palisade layer beneath each epidermis.

**Epidermis.** — The outer or epidermal cells of leaves do not bear chlorophyll, but are usually so transparent that the green mesophyll can be seen through them. They often become very thick-walled, and are in most plants devoid of all protoplasm except a thin layer lining the walls, the cavities being filled with cell sap. This sap is sometimes coloured, as in the under epidermis of begonia leaves. It is not common to find more than one layer of epidermal cells forming each surface of a leaf. The epidermis *serves to retain moisture* in the leaf and as a general *protective covering*. In desert plants the epidermis, as a rule, is very thick and has a dense cuticle, thereby preventing loss of water.

There are various *outgrowths of the epidermis*. **Hairs** are the chief of these. They may be (1) **simple**, as on primula, geranium, nægelia; (2) **once branched**, as on wall-flower; (3) **compound**, as on verbascum or mullein; (4) **disk-like**, as on shepherdia; (5) **stellate**, or star-shaped, as in certain crucifers. In some cases the hairs are **glandular**, as in Chinese primrose of the greenhouses (*Primula Sinensis*) and certain hairs of pumpkin flowers. The hairs often protect the breathing pores, or stomates, from dust and water.

**Stomates** (sometimes called **breathing-pores**) are *small openings or pores* in the epidermis of leaves and soft stems that allow the passage of air and other gases and vapours (*stomate* or *stoma*, singular; *stomates* or *stomata*, plural). They are *placed near the large intercellular spaces* of the mesophyll, usually in positions least affected by direct

sunlight. Fig. 114 shows the structure. There are two **guard-cells** at the mouth of each stomate, which may in most cases open or close the passage as the conditions of the atmosphere may require. The guard-cells contain

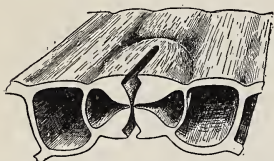


FIG. 114. — DIAGRAM OF STOMATE OF IRIS (Osterhout).

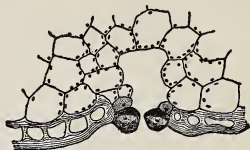


FIG. 115. — STOMATE OF IVY, showing compound guard-cells.

chlorophyll. In Fig. 115 is shown a case in which there are compound guard-cells, that of ivy. On the margins of certain leaves, as of fuchsia, impatiens, cabbage, are openings known as **water-pores**.

*Stomates are very numerous*, as will be seen from the numbers showing the pores to each square inch of leaf surface :

	Lower surface	Upper surface
Peony . . . . .	13,790	None
Holly . . . . .	63,600	None
Lilac . . . . .	160,000	None
Mistletoe . . . . .	200	200
Tradescantia . . . . .	2,000	2,000
Garden Flag (iris) . . . . .	11,572	11,572

The arrangement of stomates on the leaf *differs with each kind of plant*. Fig. 116 shows stomates and also the outlines of contiguous epidermal cells.

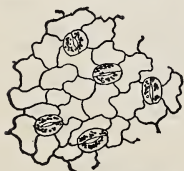


FIG. 116. — STOMATES OF GERANIUM LEAF.

The function or work of the stomates is to *regulate the passage of gases* into and out of the plant. The directly active organs or parts are guard-cells, on either side the opening. One method of opening is as follows: The



thicker walls of the guard-cells (Fig. 114) absorb water from adjacent cells, these thick walls buckle or bend and part from one another at their middles on either side the opening, causing the stomate to open, when the air gases may be taken in and the leaf gases may pass out. When moisture is reduced in the leaf tissue, the guard-cells part with some of their contents, the thick walls straighten, and the faces of the two opposite ones come together, thus closing the stomate and preventing any water vapour from passing out. *When a leaf is actively at work making new organic compounds, the stomates are usually open; when unfavourable conditions arise, they are usually closed.* They also commonly close at night, when growth (or the utilizing of the new materials) is most likely to be active. It is sometimes safer to fumigate greenhouses and window gardens at night, for the noxious vapours are less likely to enter the leaf. Dust may clog or cover the stomates. Rains benefit plants by washing the leaves as well as by providing moisture to the roots.

**Lenticels.** — On the young woody twigs of many plants (marked in osiers, cherry, birch) there are small corky spots or elevations known as lenticels (Fig. 117). They mark the location of some loose cork cells that function as stomates, for *green shoots*, as well as leaves, take in and discharge gases; that is, soft green twigs *function as leaves*. Under some of these twig stomates, corky material may form and the opening is torn and enlarged: *the lenticels are successors to the stomates.* The stomates lie in the epi-



FIG. 117. — LENTICELS ON YOUNG SHOOT OF RED OSIER (CORNUS).

dermis, but as the twig ages the epidermis perishes and the bark becomes the external layer. *Gases continue to pass in and out through the lenticels*, until the branch becomes heavily covered with thick, corky bark. With the growth of the twig, the lenticel scars enlarge lengthwise or crosswise or assume other shapes, often becoming characteristic markings.

**Fibro-vascular Bundles.** — We have studied the fibro-vascular bundles of stems (Chap. X). These stem bundles *continue into the leaves, ramifying into the veins*, carrying the soil water inwards and bringing, by diffusion, the elaborated food out through the sieve-cells. Cut across a petiole and notice the hard spots or areas in it; strip these parts lengthwise of the petiole. What are they?

**Fall of the Leaf.** — In most common deciduous plants, when the season's work for the leaf is ended, the nutritious matter may be withdrawn, and *a layer of corky cells is completed over the surface of the stem where the leaf is attached. The leaf soon falls.* It often falls even before it is killed by frost. Deciduous leaves begin to show the surface line of articulation in the early growing season. This articulation may be observed at any time during the summer. The area of the twig once covered by the petioles is called the **leaf-scar** after the leaf has fallen. In Chap. XV are shown a number of leaf-scars. In the plane tree (sycamore or buttonwood), the leaf-scar is in the form of a ring surrounding the bud, for the bud is covered by the hollowed end of the petiole; the leaf of sumac is similar. Examine with a hand lens leaf-scars of several woody plants. Note the number of bundle-scars in each leaf-scar. Sections may be cut through a leaf-scar and examined with the microscope. Note the character of cells that cover the leaf-scar surface.

SUGGESTIONS. — *To study epidermal hairs*: 75. For this study, use the leaves of any hairy or woolly plant. A good hand lens will reveal the identity of many of the coarser hairs. A dissecting microscope will show them still better. For the study of the cell structure, a compound microscope is necessary. Cross-sections may be made so as to bring hairs on the edge of the sections; or in some cases the hairs may be peeled or scraped from the epidermis and placed in water on a slide. Make sketches of the different kinds of hairs. 76. It is good practice for the pupil to describe leaves in respect to their covering: Are they smooth on both surfaces? Or hairy? Woolly? Thickly or thinly hairy? Hairs long or short? Standing straight out or lying close to the surface of the leaf? Simple or branched? Attached to the veins or to the plane surface? Colour? Most abundant on young leaves or old? 77. Place a hairy or woolly leaf under water. Does the hairy surface appear silvery? Why? *Other questions*: 78. Why is it good practice to wash the leaves of house plants? 79. Describe the leaf-scars on six kinds of plants: size, shape, colour, position with reference to the bud, bundle-scars. 80. Do you find leaf-scars on monocotyledonous plants—corn, cereal grains, lilies, canna, banana, palm, bamboo, green brier? 81. Note the table on page 88. Can you suggest a reason why there are equal numbers of stomates on both surfaces of leaves of tradescantia and flag, and none on upper surface of other leaves? Suppose you pick a leaf of lilac (or some larger leaf), seal the petiole with wax and then rub the under surface with vaseline; on another leaf apply the vaseline to the upper surface; which leaf withers first, and why? Make a similar experiment with iris or blue flag. 82. Why do leaves and shoots of house plants turn towards the light? What happens when the plants are turned around? 83. Note position of leaves of beans, clover, oxalis, alfalfa, locust, at night.

## CHAPTER XIII

### LEAVES — FUNCTION OR WORK

WE have discussed (in Chap. VIII) the work or function of roots and also (in Chap. X) the function of stems. We are now ready to complete the view of the main vital activities of plants by considering the function of the green parts (leaves and young shoots).

**Sources of Food.** — The ordinary green plant has but *two sources from which to secure food, — the air and the soil.* When a plant is thoroughly dried in an oven, the water passes off; *this water came from the soil.* The remaining part is called the **dry substance** or **dry matter**. If the dry matter is burned in an ordinary fire, only the **ash** remains; *this ash came from the soil.* The part that passed off as gas in the burning *contained the elements that came from the air*; it also contained some of those that came from the soil — all those (as nitrogen, hydrogen, chlorine) that are transformed into gases by the heat of a common fire. The part that comes from the soil (the ash) is small in amount, being considerably less than 10 per cent and sometimes less than 1 per cent. *Water is the most abundant single constituent or substance of plants.* In a corn plant of the roasting-ear stage, about 80 per cent of the substance is water. A fresh turnip is over 90 per cent water. Fresh wood of the apple tree contains about 45 per cent of water.

**Carbon.** — *Carbon enters abundantly into the composition of all plants.* Note what happens when a plant is burned

without free access of air, or smothered, as in a charcoal pit. *A mass of charcoal remains, almost as large as the body of the plant.* Charcoal is almost pure *carbon*, the ash present being so small in proportion to the large amount of carbon that we look on the ash as an impurity. Nearly half of the dry substance of a tree is carbon. Carbon goes off as *a gas* when the plant is *burned in air*. It does not go off alone, but in combination with oxygen in the form of *carbon dioxide* gas,  $\text{CO}_2$ .

**The green plant secures its carbon from the air.** In other words, much of the *solid matter* of the plant comes from *one of the gases of the air*. By volume, *carbon dioxide forms only a small fraction of 1 per cent. of the air*. It would be very disastrous to animal life, however, if this percentage were much increased, for it excludes the life-giving oxygen. Carbon dioxide is often called “foul gas.” It may accumulate in old wells, and an experienced person will not descend into such wells until they have been tested with a torch. If the air in the well will not support combustion,—that is, if the torch is extinguished,—it usually means that carbon dioxide has drained into the place. The air of a closed schoolroom often contains far too much of this gas, along with little solid particles of waste matters. Carbon dioxide is often known as carbonic acid gas.

**Appropriation of the Carbon.**—*The carbon dioxide of the air readily diffuses itself into the leaves and other green parts of the plant.* The leaf is delicate in texture, and when very young the air can diffuse directly into the tissues. The stomates, however, are the special inlets adapted for the admission of gases into the leaves and other green parts. Through these stomates, or diffusion-pores, the outside air enters into the air-spaces of the plant, and is finally absorbed by the little cells containing the living matter.

**Chlorophyll** ("leaf green") is the agent that secures the energy by means of which carbon dioxide is utilized. This material is contained in the leaf cells in the form of grains (p. 86); the grains themselves are protoplasm, only the colouring matter being chlorophyll. *The chlorophyll bodies or grains are often most abundant near the upper surface of the leaf, where they can secure the greatest amount of light.* Without this green colouring matter, there would be no reason for the large flat surfaces which the leaves possess, and no reason for the fact that the leaves are borne most abundantly at the ends of branches, where the light is most available. Plants with coloured leaves as coleus, have chlorophyll, but it is masked by other colouring matter. This other colouring matter is usually soluble in hot water: boil a coleus leaf and notice that it becomes green and the water becomes coloured.

*Plants grown in darkness are yellow and slender, and do not reach maturity.* Compare the potato sprouts that have grown from a tuber lying in a dark cellar with those that have grown normally in the bright light. The shoots have become slender, and are devoid of chlorophyll; and when the food that is stored in the tuber is exhausted these shoots will have lived useless lives. A plant that has been grown in darkness from the seed will soon die, although for a time the little seedling will grow very tall and slender. Why? *Light favours the production of chlorophyll*, and the chlorophyll is the agent in the making of *the organic carbon compounds*. Sometimes chlorophyll is found in buds and seeds, but in most cases these places are not perfectly dark. Notice how potato tubers develop chlorophyll, or become green, when exposed to light.

**Photosynthesis.**—*Carbon dioxide diffuses into the leaf; during sunlight it is used, and oxygen is given off. How*



the carbon dioxide which is thus absorbed may be used in making an organic food is a complex question, and need not be studied here; but it may be stated that carbon dioxide and water are the constituents. Complex compounds are built up out of simpler ones.

*Chlorophyll absorbs certain light rays, and the energy thus directly or indirectly obtained is used by the living matter in uniting the carbon dioxide absorbed from the air with some of the water brought up from the roots. The ultimate result usually is starch.* The process is obscure, but sugar is generally one step; and our first definite knowledge of the product begins when starch is deposited in the leaves. The process of using the carbon dioxide of the air has been known as carbon assimilation, but the term now most used is **photosynthesis** (from two Greek words meaning *light* and *placing together*.)

**Starch and Sugar.**—*All starch is composed of carbon, hydrogen, and oxygen ( $C_6H_{10}O_5$ )<sub>n</sub>.* The sugars and the substance of cell walls are very similar to it in composition. All these substances are called **carbohydrates**. In making fruit sugar from the carbon and oxygen of carbon dioxide and from the hydrogen and oxygen of the water, *there is a surplus of oxygen* ( $6 \text{ parts } CO_2 + 6 \text{ parts } H_2O = C_6H_{12}O_6 + 6 O_2$ ). It is this oxygen that is given off into the air during sunlight.

**Digestion.**—*Starch is in the form of insoluble granules. When such food material is carried from one part of the plant to another for purposes of growth or storage, it is made soluble before it can be transported.* When this starchy material is transferred from place to place, it is usually changed into sugar by the action of a diastase. *This is a process of digestion.* It is much like the change of starchy foodstuffs to sugary foods effected by the saliva.

**Distribution of the Digested Food.** — After being changed to the soluble form, *this material is ready to be used in growth*, either in the leaf, in the stem, or in the roots. With other more complex products it is then *distributed*

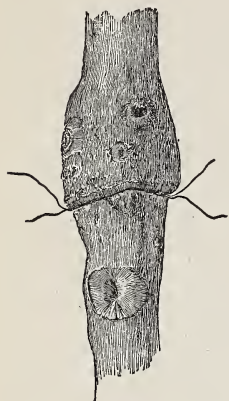


FIG. 118. — TRUNK GIRDLED BY A WIRE. See Fig. 85.

*throughout all the growing parts of the plant*; and when passing down to the root, it seems to pass more readily through the *inner bark*, in plants which have a definite bark. This gradual downward diffusion through the inner bark of materials suitable for growth is the process referred to when the “descent of sap” is mentioned. Starch and other products are often *stored in one growing season to be used in the next season*. If a tree is constricted or strangled by a wire around its trunk (Fig. 118), the digested food

cannot readily pass down and it is stored above the girdle, causing an enlargement.

**Assimilation.** — *The food from the air and that from the soil unite in the living tissues*. The “sap” that passes upwards from the roots in the growing season is made up largely of the soil water and the salts which have been absorbed in the diluted solutions (p. 67). This upward-moving water is conducted largely through certain tubular canals of the *young wood*. These cells are never continuous tubes from root to leaf; but the water passes readily from one cell or canal to another in its upward course.

The upward-moving water gradually passes to the growing parts, and everywhere in the living tissues, it is, of

course, in the most intimate contact with the soluble carbohydrates and products of photosynthesis. In the building up or reconstructive and other processes it is therefore available. We may properly conceive of certain of the simpler organic molecules as passing through a series of changes, gradually increasing in complexity. There will be formed substances containing nitrogen in addition to carbon, hydrogen, and oxygen. Others will contain also sulphur and phosphorus, and the various processes may be thought of as culminating in **protoplasm**. *Protoplasm is the living matter in plants.* It is in the cells, and is usually semifluid. Starch is not living matter. The complex process of building up the protoplasm is called **assimilation**.

**Respiration.** — *Plants need oxygen for respiration, as animals do.* We have seen that plants need the carbon dioxide of the air. To most plants the nitrogen of the air is inert, and serves only to dilute the other elements; but the *oxygen is necessary for all life.* We know that all animals need this oxygen in order to breathe or respire. In fact, they have become accustomed to it in just the proportions found in the air; and this is now best for them. When animals breathe the air once, they make it foul, because they use some of the oxygen and give off carbon dioxide. Likewise, *all living parts of the plant must have a constant supply of oxygen.* Roots also need it, for they respire. Air goes in and out of the soil by diffusion, and as the soil is heated and cooled, causing the air to expand and contract.

The oxygen passes into the air-spaces and is absorbed by the moist cell membranes. In the living cells it makes possible the formation of simpler compounds by which energy is released. This energy enables the plant to

work and grow, and the final products of this action are *carbon dioxide and water*. As a result of the use of this oxygen by night and by day, plants give off carbon dioxide. *Plants respire; but since they are stationary, and more or less inactive, they do not need so much oxygen as animals do, and they do not give off so much carbon dioxide*. A few plants in a sleeping room need not disturb one more than a family of mice. It should be noted, however, that germinating seeds respire vigorously, hence they consume much oxygen; and opening buds and flowers are likewise active.

**Transpiration.** — Much more water is absorbed by the roots than is used in growth, *and this surplus water passes from the leaves into the atmosphere by an evaporation process known as transpiration*. Transpiration takes place more abundantly from the under surfaces of leaves, and through the pores or stomates. A sunflower plant of the height of a man, during an active period of growth, gives off a quart of water per day. A large oak tree may transpire 150 gallons per day during the summer. For every ounce of dry matter produced, it is estimated that 15 to 25 pounds of water usually passes through the plant.

*When the roots fail to supply to the plant sufficient water to equalize that transpired by the leaves, the plant wilts*. Transpiration from the leaves and delicate shoots is increased by all the conditions which increase evaporation, such as higher temperature, dry air, or wind. The stomata open and close, tending to regulate transpiration as the varying conditions of the atmosphere affect the moisture content of the plant. However, in periods of drought or of very hot weather, and especially during a hot wind, the closing of these stomates cannot sufficiently prevent evaporation. The roots may be very active and yet fail to absorb sufficient moisture to equalize that given

off by the leaves. The plant shows the effect (how?). On a hot dry day, note how the leaves of corn "roll" towards afternoon. Note how fresh and vigorous the same leaves appear early the following morning. Any injury to the roots, such as a bruise, or exposure to heat, drought, or cold may cause the plant to wilt.

Water is forced up by root pressure or sap pressure. (Exercise 99.) Some of the dew on the grass in the morning may be the water forced up by the roots; some of it is the condensed vapour of the air.

*The wilting of a plant is due to the loss of water from the cells.* The cell walls are soft, and collapse. A toy balloon will not stand alone until it is inflated with air or liquid. In the woody parts of the plant the cell walls may be stiff enough to support themselves, even though the cell is empty. Measure the contraction due to wilting and drying by tracing a fresh leaf on page of notebook, and then tracing the same leaf after it has been dried between papers. The softer the leaf, the greater will be the contraction.

**Storage.**—We have said that starch may be stored in twigs to be used the following year. The very early flowers on fruit trees, especially those that come before the leaves, and those that come from bulbs, as crocuses and tulips, are supported by the starch or other food that was organized the year before. Some plants have very special storage reservoirs, as the potato, in this case being a thickened stem although growing underground. (Why a thickened stem? p. 84.) It is well to make the starch test on winter twigs and on all kinds of thickened parts, as tubers and bulbs.

**Carnivorous Plants.**—Certain plants capture insects and other very small animals and utilize them to some extent as food. Such are the sundew, which has on the leaves

sticky hairs that close over the insect; the Venus's fly-trap of the Southern States, in which the halves of the leaves



FIG. 119. — THE COMMON PITCHER PLANT (*Sarracenia purpurea*) showing the tubular leaves and the odd, long-stalked flowers.

close over the prey like the jaws of a steel trap; and the various kinds of pitcher plants that collect insects and other organic matter in deep, water-filled, flask-like leaf pouches (Fig. 119).

The sundew and the Venus's fly-trap are sensitive to contact. Other plants are *sensitive to the touch* without being insectivorous. The common cultivated sensitive plant is an example. This is readily grown from seeds (sold by seedsmen) in a warm place. Related wild plants in the south are sensitive. The

utility of this sensitiveness is not understood.

**Parts that Simulate Leaves.** — We have learned that leaves are endlessly modified to suit the conditions in which the plant is placed. The most marked modifications are in adaptation to light. On the other hand, *other organs often perform the functions of leaves*. Green shoots function as leaves. These shoots may look like leaves, in which case they are called **cladophylla**. The foliage of common asparagus is made up of fine branches: the real morphological leaves are the minute dry functionless scales at the bases of these branchlets. (What reason is there for calling them leaves?) The broad "leaves" of the florist's smilax are cladophylla. Where are the leaves on this plant? In most of the cacti, the entire plant body performs the functions of leaves until the parts become cork-bound.



Leaves are sometimes modified to perform other functions than the vital processes: they may be tendrils, as the terminal leaflets of pea and sweet pea; or spines, as in barberry. Not all spines and thorns, however, represent modified leaves: some of them (as of hawthorns, osage orange, honey locust) are branches.

**SUGGESTIONS.**—*To test for chlorophyll.* **84.** Purchase about a gill of wood alcohol. Secure a leaf of geranium, clover, or other plant that has been exposed to sunlight for a few hours, and, after dipping it for a minute in boiling water, put it in a white cup with sufficient alcohol to cover. Place the cup in a shallow pan of hot water on the stove where it is not hot enough for the alcohol to take fire. After a time the chlorophyll is dissolved by the alcohol which has become an intense green. Save this leaf for the starch experiment (Exercise 85). Without chlorophyll, the plant cannot appropriate the carbon dioxide of the air. *Starch and photosynthesis.* **85.** Starch is present in the green leaves which have been exposed to sunlight; but in the dark no starch can be formed from carbon dioxide. Apply iodine to the leaf from which the chlorophyll was dissolved in the previous experiment. Note that the leaf is coloured purplish-brown throughout. The leaf contains starch. **86.** Secure a leaf from a plant which has been in the dark for about two days. Dissolve the chlorophyll as before, and attempt to stain this leaf with iodine. No purplish-brown colour is produced. This shows that the starch manufactured in the leaf may be entirely removed during darkness.

**87.** Secure a plant which has been kept in darkness for twenty-four hours or more. Split a small cork



FIG. 120. — EXCLUDING LIGHT AND  $\text{CO}_2$  FROM PART OF A LEAF.



FIG. 121. — THE RESULT.

and pin the two halves on opposite sides of one of the leaves, as shown in Fig. 120. Place the plant in the sunlight again. After a morning of bright sunshine dissolve the chlorophyll in this leaf with alcohol; then stain the leaf with the iodine. Notice that the leaf is stained deeply except where the cork was; there sunlight and carbon dioxide were excluded, Fig. 121. There is no starch in the

covered area. **88.** Plants or parts of plants that have developed no chlorophyll can form no starch. Secure a variegated leaf of coleus, ribbon grass, geranium, or of any plant showing both white and green areas. On a day of bright sunshine, test one of these leaves by the alcohol and iodine method for the presence of starch. Observe that the parts devoid of green colour have formed no starch. However, after starch has once been formed in the leaves, it may be changed into soluble substances and removed, to be again converted into starch in certain other parts of the living tissues. *To test the giving off of oxygen by day.*

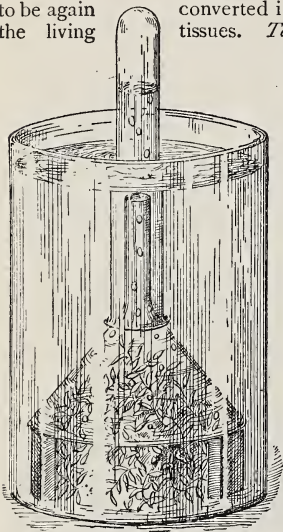


FIG. 122.—TO SHOW THE ESCAPE OF OXYGEN.

**89.** Make the experiment illustrated in Fig. 122. Under a funnel in a deep glass jar containing fresh spring or stream water place fresh pieces of the common waterweed elodea (or anacharis). Have the funnel considerably smaller than the vessel, and support the funnel well up from the bottom so that the plant can more readily get all the carbon dioxide available in the water. Why would boiled water be undesirable in this experiment? For a home-made glass funnel, crack the bottom off a narrow-necked bottle by pressing a red-hot poker or iron rod against it and leading the crack around the bottle. Invert a test-tube over the stem of the funnel. In sunlight bubbles of oxygen will arise and collect in the test-tube. If a sufficient quantity of oxygen has collected, a lighted taper inserted in the

tube will glow with a brighter flame, showing the presence of oxygen in greater quantity than in the air. Shade the vessel. Are bubbles given off? For many reasons it is impracticable to continue this experiment longer than a few hours. **90.** A simpler experiment may be made if one of the waterweeds Cabomba (water-lily family) is available. Tie a number of branches together so that the basal ends shall make a small bundle. Place these in a large vessel of spring water, and insert a test-tube of water as before over the bundle. The bubbles will arise from the cut surfaces. Observe the bubbles on pond scum and waterweeds on a bright day. *To illustrate the results of respiration*

(CO<sub>2</sub>). 91. In a jar of germinating seeds (Fig. 123) place carefully a small dish of limewater and cover tightly. Put a similar dish in



FIG. 123. — TO ILLUSTRATE A PRODUCT OF RESPIRATION.

another jar of about the same air space. After a few hours compare the cloudiness or precipitate in the two vessels of limewater.

92. Or, place a growing plant in a deep covered jar away from the light, and after a few hours insert a lighted candle or splinter.

93. Or, perform a similar experiment with fresh roots of beets or turnips (Fig. 124) from which the leaves are mostly removed. In this case,

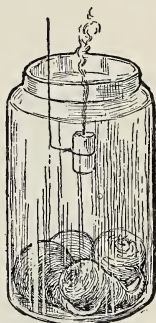


FIG. 124. — RESPIRATION OF THICK ROOTS.

the jar need not be kept dark; why?

*To test transpiration.* 94. Cut a succulent shoot of any plant, thrust the end of it through a hole in a cork, and stand it in a small bottle of water. Invert over this a fruit jar, and observe

that a mist soon accumulates on the inside of the glass. In time drops of water form. 95. The experiment may be varied as shown in Fig. 125. 96. Or, invert the fruit jar over an entire plant, as shown in Fig. 126, taking care to cover the soil with oiled paper or rubber cloth to prevent evaporation from the soil. 97. The test may also be made by placing the pot, properly protected, on bal-

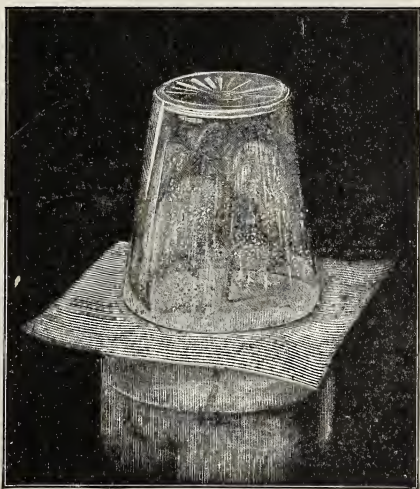


FIG. 125. — TO ILLUSTRATE TRANSPIRATION.

ances, and the loss of weight will be noticed (Fig. 127). 98. Cut a winter twig, seal the severed end with wax, and allow the twig to lie several days. It shrivels. There must be some upward movement of water even in winter, else plants would shrivel and die.

99. *To illustrate sap pressure.* The upward movement of sap water often takes place under considerable force. The cause of this force, known as *root pressure*, is not well understood. The pressure varies with different plants and under different conditions. To illustrate :

cut off a strong-growing small plant near the ground. By means of a bit of rubber tube attach a glass tube with a bore of approximately the diameter of the stem. Pour in a little water. Observe the rise of the water due to the pressure from below

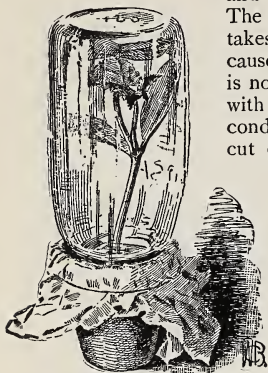


FIG. 126. — TO ILLUSTRATE TRANSPIRATION.

low (Fig. 128). Some plants yield a large amount of water under a pressure sufficient to raise a column several feet ; others force out little, but under considerable pressure (less easily demonstrated). *The vital processes (i.e., the life processes).*

100. The pupil having studied roots, stems, and leaves, should now be able to describe the main vital functions of plants : what is the root function?

stem function? leaf function? 101. What is meant by the "sap"? 102. Where and how does the plant secure its water? oxygen? carbon? hydrogen? nitrogen? sulphur? potassium?

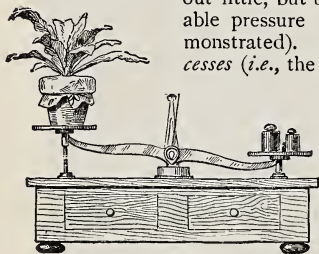


FIG. 127 — LOSS OF WATER.



FIG. 128. — TO SHOW SAP PRESSURE.

calcium? iron? phosphorus? 103. Where is all the starch in the world made? What does a starch-factory establishment do? Where are the real starch factories? 104. In what part of the twenty-four hours do plants grow most rapidly in length? When is food formed and stored most rapidly? 105. Why does corn or cotton turn yellow in a long rainy spell? 106. If stubble, corn stalks, or cotton stalks are burned in the field, is as much plant-food returned to the soil as when they are ploughed under? 107. What process of plants is roughly analogous to perspiration of animals? 108. What part of the organic world uses raw mineral for food? 109. Why is earth banked over celery to blanch it? 110. Is the amount of water transpired equal to the amount absorbed? 111. Give some reasons why plants very close to a house may not thrive or may even die. 112. Why are fruit-trees pruned or thinned out as in Fig. 129? *Proper balance between top and root.* 113. We have learned that the leaf parts and the root parts work together. They may be said to balance each other in activities, the root supplying the top and the top supplying the root (how?). If half the roots were cut from a tree, we should expect to reduce the top also, particularly if the tree is being transplanted. How would you prune a tree or bush that is being transplanted? Fig. 130 may be suggestive.

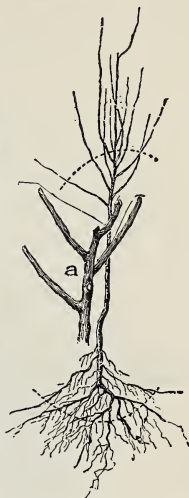


FIG. 130. — AN APPLE TREE, with suggestions as to pruning when it is set in the orchard. At *a* is shown a pruned top.



FIG. 129. — BEFORE AND AFTER PRUNING.



## CHAPTER XIV

### DEPENDENT PLANTS

THUS far we have spoken of plants that have roots and foliage and that depend on themselves. They collect the raw materials and make them over into assimilable food. They are **independent**. Plants without green foliage can-



FIG. 131.—A MUSHROOM, example of a saprophytic plant. This is the edible cultivated mushroom.

not make food; they must have it made for them or they die. They are **dependent**. A sprout from a potato tuber in a dark cellar cannot collect and elaborate carbon dioxide. It lives on the food stored in the tuber.

*All plants with naturally white or blanched parts are dependent.* Their leaves do not develop. They live on organic matter—that which has been made by a plant or elaborated by an animal. The dodder, Indian pipe, beech drop, coral root among flower-bearing plants, also mushrooms and other fungi (Figs. 131, 132) are examples. The dodder is common in swales, being conspicuous late in the season from its thread-like yellow or orange stems spreading over the herbage of other plants. One kind attacks alfalfa and is a bad pest. The seeds germinate in the spring, but as soon as the twining stem at-





FIG. 132. — A PARASITIC FUNGUS, magnified. The mycelium, or vegetative part, is shown by the dotted-shaded parts ramifying in the leaf tissue. The rounded haustoria projecting into the cells are also shown. The long fruiting parts of the fungus hang from the under surface of the leaf.

*they injure or kill their host.* The mass of hyphæ of a fungus is called **mycelium**. Some of the hyphæ finally grow out of the leaf and produce spores or reproductive cells that answer the purpose of seeds in distributing the plant (*b*, Fig. 132).

A plant that lives on dead or decaying matter is a **saprophyte**. Mushrooms (Fig. 131) are examples; they live on the decaying matter in the soil. Mould on bread and cheese is an

taches itself to another plant, the dodder dies away at the base and becomes wholly dependent. It produces flowers in clusters and seeds itself freely (Fig. 133).

**Parasites and Saprophytes.** — A plant that is dependent on a living plant or animal is a **parasite**, and the plant or animal on which it lives is the **host**. The dodder is a true parasite; so are the rusts, mildews, and other fungi that attack leaves and shoots and injure them.

The threads of a parasitic fungus usually creep through the intercellular spaces in the leaf or the stem and send suckers (or haustoria) into the cells (Fig. 132). The threads (or the hyphæ) clog the air-spaces of the leaf and often plug the stomates, and they also appropriate and disorganize the cell fluids; *thus*

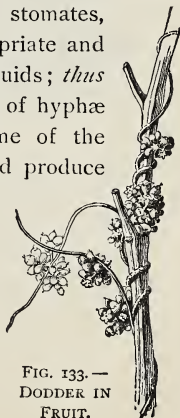


FIG. 133. — DODDER IN FRUIT.

example. Lay a piece of moist bread on a plate and invert a tumbler over it. In a few days it will be mouldy. The spores were in the air, or perhaps they had already fallen on the bread but had not had opportunity to grow. Most green plants are unable to make any direct use of the humus or vegetable mould in the soil, for they are not

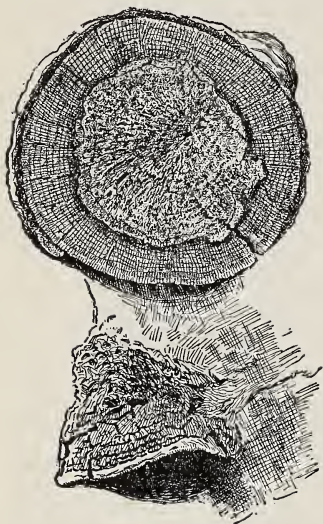


FIG. 134. — TINDER FUNGUS (*Polyporus igniarius*) on beech log. The external part of the fungus is shown below; the heart-rot injury above.

saprophytic. The shelf-fungi (Fig. 134) are saprophytes. They are common on logs and trees. Some of them are perhaps partially parasitic, extending the mycelium into the wood of the living tree and causing it to become black-hearted (Fig. 134).

Some parasites spring from the ground, as other plants do, but they are *parasitic on the roots of their hosts*. Some parasites may be *partially parasitic* and *partially saprophytic*. Many (perhaps most) of these ground saprophytes are aided in securing their

food by soil fungi, which spread their delicate threads over the root-like branches of the plant and act as intermediaries between the food and the saprophyte. These fungus-covered roots are known as **mycorrhizas** (meaning "fungus root"). Mycorrhizas are not peculiar to saprophytes. They are found on many wholly independent plants, as,

for example, the heaths, oaks, apples, and pines. It is probable that the fungous threads perform some of the offices of root-hairs to the host. On the other hand, the fungus obtains some nourishment from the host. The association seems to be mutual.

Saprophytes break down or decompose organic substances. Chief of these saprophytes are many microscopic organisms known as bacteria (Fig. 135). These innumerable organisms are immersed in water or in dead animals and



FIG. 135.—BACTERIA OF SEVERAL FORMS, much magnified.

plants, and in all manner of moist organic products. By breaking down organic combinations, *they produce decay*. Largely through their agency, and that of many true but microscopic fungi, *all things pass into soil and gas*. Thus are the bodies of plants and animals removed and the continuing round of life is maintained.

*Some parasites are green-leaved*. Such is the mistletoe (Fig. 136). They anchor themselves on the host and absorb its juices, but they also appropriate and use



FIG. 136.—AMERICAN MISTLETOE GROWING ON A WALNUT BRANCH.

the carbon dioxide of the air. In some small groups of bacteria a process of organic synthesis has been shown to take place.

**Epiphytes.**—To be distinguished from the dependent plants are those that grow on other plants without taking food from them. These are green-leaved plants whose roots burrow in the bark of the host plant and perhaps derive some food from it, but which subsist chiefly on materials that they secure from air dust, rain water, and the air. These plants are **epiphytes** (meaning “upon plants”) or air plants.

Epiphytes abound in the tropics. Certain orchids are among the best known examples (Fig. 37). The Spanish moss or *tillandsia* of the South is another. Mosses and lichens that grow on trees and fences may also be called epiphytes. In the struggle for existence, the plants probably *have been driven to these special places* in which to find opportunity to grow. Plants grow where they must, not where they will.

**SUGGESTIONS.**—**114.** Is a puffball a plant? Why do you think so? **115.** Are mushrooms ever cultivated, and where and how? **116.** In what locations are mushrooms and toadstools usually found? (There is really no distinction between mushrooms and toadstools. They are all mushrooms.) **117.** What kinds of mildew, blight, and rust do you know? **118.** How do farmers overcome potato blight? Apple scab? Or any other fungous “plant disease”? **119.** How do these things injure plants? **120.** What is a plant disease? **121.** The pupil should know that every spot or injury on a leaf or stem is caused by something,—as an insect, a fungus, wind, hail, drought, or other agency. How many uninjured or perfect leaves are there on the plant growing nearest the schoolhouse steps? **122.** Give formula for Bordeaux mixture and tell how and for what it is used.

## CHAPTER XV

### WINTER AND DORMANT BUDS

A bud is a growing point, terminating an axis either long or short, or being the starting point of an axis. *All branches spring from buds.* In the growing season the bud is active; later in the season it ceases to increase the axis in length, and as winter approaches the growing point becomes more or less thickened and covered by protecting scales, in preparation for the long resting season. This resting, dormant, or winter body is what is commonly spoken of as a "bud." A winter bud may be defined as an *inactive covered growing point*, waiting for spring.

*Structurally, a dormant bud is a shortened axis or branch, bearing miniature leaves or flowers or both, and protected by a covering.* Cut in two, lengthwise, a bud of the horse-chestnut or other plant that has large buds.



FIG. 137. — BUD OF APRICOT, showing the miniature leaves.

With a pin separate the tiny leaves. Count them. Examine the big bud of the rhubarb as it lies under the ground in late winter or early spring; or the crown buds of asparagus, hepatica, or other early spring plants. Dissect large buds of the apple and pear (Figs. 137, 138).



FIG. 138. — BUD OF PEAR, showing both leaves and flowers. The latter are the little knobs in the centre.

*The bud is protected by firm and dry scales.* These scales are modified leaves. The scales fit close. Often

the bud is protected by varnish (see horse-chestnut and the balsam poplars). Most winter buds are more or less woolly. Examine some of them under a lens. As we might expect, bud coverings are most prominent in cold and dry climates. Sprinkle water on velvet or flannel, and note the result and give a reason.

All winter buds give rise to branches, *not to leaves alone*; that is, the leaves are borne on the lengthening axis. Sometimes the axis, or branch, remains very short,—so short that it may not be noticed. Sometimes it grows several feet long.

*Whether the branch grows large or not depends on the chance it has*,—position on the plant, soil, rainfall, and

many other factors. The new shoot is the unfolding and enlarging of the tiny axis and leaves that we saw in the bud. If the conditions are congenial, the shoot may form more leaves than were tucked away in the bud. The length of the shoot usually depends more on the length of the internodes than on the number of leaves.



FIG. 139. — LEAF-SCARS. — *Ailanthus*.

**Where Buds are.** — *Buds are borne in the axils of the leaves*,—in the acute angle that the leaf makes with the stem. When the leaf is growing in the summer, a bud is forming above it. When the leaf falls, the bud remains, and a scar marks the place of the leaf. Fig. 139 shows the large leaf-scars of *ailanthus*. Observe those on the horse-chestnut, maple, apple, pear, basswood, or any other tree or bush.

Sometimes two or more buds are borne in one axil; the extra ones are **accessory** or **supernumerary** buds. Observe them in the Tartarian honeysuckle (common in yards),



walnut, butternut, red maple, honey locust, and sometimes in the apricot and peach.

If the bud is at the end of a shoot, however short the shoot, it is called a **terminal bud**. *It continues the growth of the axis in a direct line.* Very often three or more buds are clustered at the tip (Fig. 140); and in this case there may be more buds than leaf scars. Only one of them, however, is strictly terminal.

A bud in the axil of a leaf is an **axillary** or **lateral bud**. Note that there is normally at least one bud in the axil of every leaf on a tree or shrub in late summer and fall. The axillary buds, if they grow, are the *starting points of new shoots the following season*. If a leaf is pulled off early in summer, what will become of the young bud in its axil? Try this.

*Bulbs and cabbage heads may be likened to buds*; that is, they are condensed stems, with scales or modified leaves

densely overlapping and forming a rounded body (Fig. 141). They differ from true buds, however, in the fact that they are condensations of whole main stems rather than embryo stems borne in the axils of



FIG. 140. — TERMINAL BUD BETWEEN TWO OTHER BUDS. — Currant.



FIG. 141. — A GIGANTIC BUD. — Cabbage.

leaves. But bulblets (as of tiger lily) may be scarcely distinguishable from buds on the one hand and from bulbs

on the other. Cut a cabbage head in two, lengthwise, and see what it is like.

The buds that appear on roots are unusual or abnormal,—they occur only occasionally and in no definite order. Buds appearing in unusual places on any part of the plant are called **adventitious buds**. Such usually are the buds that arise when a large limb is cut off, and

from which suckers or water sprouts arise.

### How Buds Open.

—*When the bud swells, the scales are pushed apart, the little axis elongates and pushes out.* In most plants the outside scales



FIG. 142.—  
FRUIT-BUD  
OF PEAR.



FIG. 143.—THE  
OPENING OF  
THE PEAR  
FRUIT-BUD.



FIG. 144.—OPEN-  
ING PEAR  
LEAF-BUD.



FIG. 145.—OPEN-  
ING OF THE  
PEAR-BUD.

fall very soon, *leaving a little ring of scars*. With terminal buds, this ring marks the end

of the year's growth. How? Notice peach, apple, plum, willow, and other plants. In

some others, all the scales grow for a time, as in the pear (Figs. 142, 143, 144). In other plants the inner bud scales become green and almost leaf-like. See the maple and hickory.

**Sometimes Flowers come out of the Buds.**—Leaves may or may not accompany the flowers. We saw the embryo flowers in Fig. 138. The bud is shown again in Fig. 142. In Fig. 143 it is opening. In Fig. 145

it is more advanced, and the woolly unformed flowers are appearing. In Fig. 146 the growth is more advanced.



FIG. 146. — A SINGLE FLOWER IN THE PEAR CLUSTER, as seen at 7 A.M. on the day of its opening. At 10 o'clock it will be fully expanded.



FIG. 147. — THE OPENING OF THE FLOWER-BUD OF APRICOT.

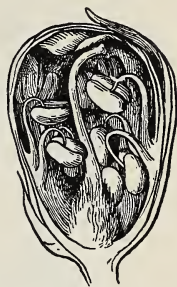


FIG. 148. — APRICOT FLOWER-BUD, enlarged.

Buds that contain or produce only leaves are **leaf-buds**. Those which contain only flowers are **flower-buds** or **fruit-buds**. The latter occur on peach, almond, apricot, and many very early spring-flowering plants. The single flower is emerging from the apricot bud in Fig. 147. A longitudinal section of this bud, enlarged, is shown in Fig. 148. Those that contain both leaves and flowers are **mixed buds**, as in pear, apple, and most late spring-flowering plants.

*Fruit buds are usually thicker or stouter than leaf-buds. They are borne in different positions on different plants. In some plants (apple, pear) they are on the ends of short branches or spurs; in others (peach, red maple) they are along the sides of the last year's growths. In Fig. 149 are shown*

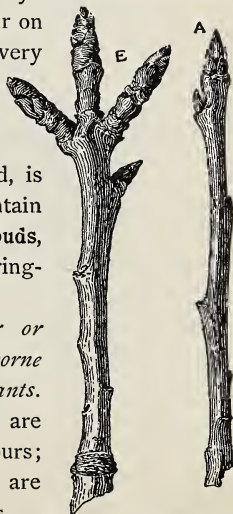


FIG. 149. — FRUIT-BUDS AND LEAF-BUDS OF PEAR.

three fruit-buds and one leaf-bud on *E*, and leaf-buds on *A*. See also Figs. 150, 151, 152, 153, and explain.



FIG. 150. — FRUIT-BUDS OF APPLE ON SPURS: a dormant bud at the top.



FIG. 151. — CLUSTER OF FRUIT-BUDS OF SWEET CHERRY, with one pointed leaf-bud in centre.



FIG. 152. — TWO FRUIT-BUDS OF PEACH with a leaf-bud between.



FIG. 153. — OPENING OF LEAF-BUDS AND FLOWER-BUDS OF APPLE.

*"The burst of spring"* means in large part the opening of the buds. *Everything was made ready the fall before. The embryo shoots and flowers were tucked away, and the food was stored.* The warm rain falls, and the shutters open and the sleepers wake.

**Arrangement of Buds.**—We have found that leaves are usually arranged in a definite order; buds are borne in the axils of leaves: therefore *buds must exhibit phyllotaxy.*

Moreover, branches grow from buds: branches, therefore, should show a definite arrangement. Usually, however, they do not show this arrangement because *not all the buds grow and not all the branches live*. (See Chaps. II and III.) It is apparent, however, that the mode of arrangement of buds determines to some extent the form of the tree. Compare bud arrangement in pine or fir with that in maple or apple.



FIG. 154.—OAK SPRAY. How are the leaves borne with reference to the annual growths?

The uppermost buds on any twig, if they are well matured, are usually the larger and stronger and they are the most likely to grow the next spring; therefore, branches tend to be arranged in tiers (particularly well marked in spruces and firs). See Fig. 154 and explain it.

**Winter Buds show what has been the Effect of Sunlight.**—Buds are borne in the axils of the leaves, and *the size or the vigour of the leaf determines to a large extent the size of the bud*. Notice that, in most instances, *the largest buds are nearest the tip* (Fig. 157). If the largest buds are not near the tip, there is some special reason for it. Can you state it? Examine the shoots on trees and bushes.

SUGGESTIONS. — Some of the best of all observation lessons are those made on dormant twigs. There are many things to be learned, the eyes are trained, and the specimens are everywhere accessible. **123.** At whatever time of year the pupil takes up the study of branches, he should look for three things: the ages of the various parts, the relative positions of the buds and the leaves, the different sizes of similar or comparable buds. If it is late in spring or early in summer, he should watch the development of the buds in the axils, and he should determine whether the strength or size of the bud is in any way related to the size and the vigour of the subtending (or supporting) leaf. The sizes of buds should also be noted on leafless twigs, and the sizes of the former leaves may be inferred from the size of the leaf-scar below the bud. The pupil should keep in mind the fact of the struggle for food and light, and its effects on the developing buds. **124. *The bud and the branch.*** A twig cut from an apple tree in early spring is shown in Fig. 155. The most hasty observation shows that it has various parts, or members. It seems to be divided at the point *f* into two parts. It is evident that the part from *f* to *h* grew last year, and that the part below *f* grew two years ago. The buds on the two parts are very unlike, and these differences challenge investigation. — In order to understand this seemingly lifeless twig, it will be necessary to see it as it looked late last summer (and this condition is shown in Fig. 156). The part from *f* to *h*, — which has just completed its growth, — is seen to have its leaves growing singly. In every axil (or angle which the leaf makes when it joins the shoot) is a bud. The leaf starts first, and as the season advances the bud forms in its axil. When the leaves have fallen, at the approach of winter, the buds remain, as seen in Fig. 155. Every bud on the last year's growth of a winter twig, therefore, marks the position occupied by a leaf when the shoot was growing. — The part below *f*, in Fig. 156, shows a wholly different arrangement. The leaves are two or more together (*aaaa*), and there are buds without leaves (*bbbb*). A year ago this part looked like the present shoot from *f* to *h*, — that is, the leaves were single, with a bud in the axil of each. It is now seen that some of these bud-like parts are longer than others, and that the longest ones are those which have leaves. It must be because of the leaves that they have increased in length. The body *c* has lost its leaves through some accident, and its growth has ceased. In other words, the parts at *aaaa* are like the shoot *fh*, except that they are shorter, and they are of the same age. One grew from the end or terminal bud of the main branch, and the others from the side or lateral buds. Parts or bodies that bear leaves are, therefore, branches. — The buds at *bbbb* have no leaves, and they remain the same



size that they were a year ago. They are dormant. The only way for a mature bud to grow is by making leaves for itself, for a leaf



FIG. 155.—AN  
APPLE TWIG.

FIG. 156.— Same twig before leaves fell.

will never stand below it again. The twig, therefore, has buds of two ages,—those at *bbbb* are two seasons old, and those on the

tips, of all the branches (*aaaa, h*), and in the axil of every leaf, are one season old. It is only the terminal buds that are not axillary. When the bud begins to grow and to put forth leaves, it gives rise to a branch, which, in its turn, bears buds. — It will now be interesting to determine why certain buds gave rise to branches and why others remained dormant. The strongest shoot or branch of the year is the terminal one (*fh*). The next in strength is the uppermost lateral one, and the weakest shoot is at the base of the twig. The dormant buds are on the under side (for the twig grew in a horizontal position). All this suggests that those buds grew which had the best chance, — the most sunlight and room. There were too many buds for the space, and in the struggle for existence those that had the best opportunities made the largest growth. This struggle for existence began a year ago, however, when the buds on the shoot below *f* were forming in the axils of the leaves, for the buds near the tip of the shoot grew larger and stronger than those near its base. The growth of one year, therefore, is very largely determined by the conditions under which the buds were formed the previous year. *Other bud characters.* **125.** It is easy to see the swelling of the bud in a room in winter. Secure branches of trees and shrubs, two to three feet long, and stand them in vases or jars, as you would flowers. Renew the water frequently and cut off the lower ends of the shoots occasionally. In a week or two the buds will begin to swell. Of red maple, peach, apricot, and other very early-flowering things, flowers may be obtained in ten to twenty days. **126.** The shape, size, and colour of the winter buds are different in every kind of plant. By the buds alone botanists are often able to distinguish the kinds of plants. Even such similar plants as the different kinds of willows have good bud characters. **127.** Distinguish and draw fruit-buds of apple, pear, peach, plum, and other trees. If different kinds of maples grow in the vicinity, secure twigs of the red or swamp maple, and the soft or silver maple, and compare the buds with those of the sugar maple and the Norway maple. What do you learn?



FIG. 157. — BUDS OF THE HICKORY.

## CHAPTER XVI

### BUD PROPAGATION

WE have learned (in Chap. VI) that plants propagate by means of seeds. *They also propagate by means of bud parts,—as rootstocks (rhizomes), roots, runners, layers, bulbs.* The pupil should determine how any plant in which he is interested naturally propagates itself (or spreads its kind). Determine this for raspberry, blackberry, strawberry, June-grass or other grass, nut-grass, water lily, May apple or mandrake, burdock, Irish potato, sweet potato, buckwheat, cotton, pea, corn, sugar-cane, wheat, rice.

Plants may be *artificially propagated* by similar means, as by *layers, cuttings, and grafts*. The last two we may discuss here.

**Cuttings in General.**—*A bit of a plant stuck into the ground stands a chance of growing; and this bit is a cutting.* Plants have preferences, however, as to the kind of bit which shall be used, but *there is no way of telling what this preference is except by trying.* In some instances this preference has not been discovered, and we say that the plant cannot be propagated by cuttings.

Most plants prefer that the cutting be made of the **soft** or **growing parts** (called “wood” by gardeners), of which the “slips” of geranium and coleus are examples. Others grow equally well from cuttings of the **hard** or **mature parts** or **wood**, as currant and grape; and in some instances this mature wood may be of roots, as in the blackberry. In some cases cuttings are made of tubers, as in the Irish

potato (Fig. 60). Pupils should make cuttings now and then. If they can do nothing more, they can make cuttings of potato, as the farmer does; and they can plant them in a box in the window.

**The Softwood Cutting.**—The softwood cutting is made from tissue that is still growing, or at least from that which is not dormant. *It comprises one or two joints, with*



FIG. 158. — GERANIUM CUTTING.



FIG. 159. — ROSE CUTTING.

*a leaf attached* (Figs. 158, 159). It must not be allowed to wilt. Therefore, it must be *protected from direct sunlight and dry air until it is well established*; and *if it has many leaves, some of them should be removed, or at least cut in two, in order to reduce the evaporating surface*. The soil should be uniformly moist. The pictures show the depth to which the cuttings are planted.

For most plants, the proper age or maturity of wood for the making of cuttings may be determined by giving the *twig a quick bend: if it snaps and hangs by the bark, it is in proper condition; if it bends without breaking, it is too young and soft or too old; if it splinters, it is too old and woody*. The tips of strong upright shoots usually make the best cuttings. Preferably, each cutting should have a joint or node near its base; and if the internodes are very short it may comprise two or three joints.

*The stem of the cutting is inserted one third or more of its length in clean sand or gravel, and the earth is pressed firmly about it.* A newspaper may be laid over the bed to exclude the light—if the sun strikes it—and to prevent too rapid evaporation. The soil should be moist clear through, not on top only.

*Loose sandy or gravelly soil is used.* Sand used by masons is good material in which to start most cuttings; or fine gravel—sifted of most of its earthy matter—may be used. Soils are avoided which contain much decaying organic matter, for these soils are breeding places of fungi, which attack the soft cutting and cause it to “damp off,” or to die at or near the surface of the ground. If the cuttings are to be grown in a window, put three or four inches of the earth in a shallow box or a pan. A soap box cut in two lengthwise, so that it makes a box four or five inches deep—as a gardener’s flat—is excellent (Fig. 160). Cuttings of common plants, as geranium, coleus,

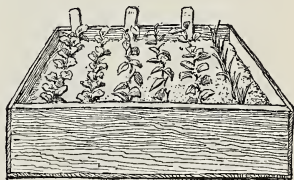


FIG. 160. — CUTTING-BOX.



FIG. 161. — VERBENA CUTTING READY FOR TRANSPLANTING.

fuchsia, carnation, are kept at a living-room temperature. As long as the cuttings look bright and green, they are in good condition. It may be a month before roots form. When roots have formed, the plants begin to make new leaves at the tip. Then they may be transplanted into other boxes or into pots. The verbena in Fig. 161 is just ready for transplanting.



FIG. 162. — OLD GERANIUM PLANT CUT BACK TO MAKE IT THROW OUT SHOOTS FROM WHICH CUTTINGS CAN BE MADE.

It is not always easy to find growing shoots from which to make the cuttings. The best practice, in that case, is to cut back an old plant, then keep it warm and well watered, and thereby force it to throw out new shoots. The old geranium plant from the window garden, or the one taken up from the lawn bed, may be treated this way (see Fig. 162). The best plants of geranium and coleus and most win-

dow plants are those which are not more than one year old. *The geranium and fuchsia cuttings which are made in January, February, or March will give compact blooming plants for the next winter; and thereafter new ones should take their places (Fig. 163).*

**The Hardwood Cutting.** — *Best results with cuttings of mature wood are*



FIG. 163. — EARLY WINTER GERANIUM, from a spring cutting.



*secured when the cuttings are made in the fall and then buried until spring in sand in the cellar.* These cuttings are usually six to ten inches long. They are not idle while they rest. The lower end calluses or heals, and the roots form more readily when the cutting is planted in the spring. But if the proper season has passed, take cuttings at any time in winter, plant them in a deep box in the window, and watch. They will need no shading or special care. Grape, currant, gooseberry, willow, and poplar readily take root from the hardwood. Fig. 164 shows a currant cutting. It has only one bud above the ground.

**The Graft.** — *When the cutting is inserted in a plant rather than in the soil, it is a graft; and the graft may grow.* In this case the cutting grows fast to the other plant, and the two become one. When the cutting is inserted in a plant, it is no longer called a cutting but a **scion**; and the plant in which it is inserted is called the **stock**. Fruit trees are grafted *in order that a certain variety or kind may be perpetuated*, as a Baldwin or Ben Davis variety of apple, Seckel or Bartlett pear, Navel or St. Michael orange.

*Plants have preferences as to the stocks on which they will grow; but we can find out what their choice is only by making the experiment.* The pear grows well on the quince, but the quince does not thrive on the pear. The pear grows on some of the hawthorns, but it is an unwilling subject on the apple. Tomato plants will grow on potato plants and potato plants on tomato plants.



FIG. 164. — CURRANT CUTTING.

When the potato is the root, both tomatoes and potatoes may be produced, although the crop will be very small; when the tomato is the root, neither potatoes nor tomatoes will be produced. Chestnut will grow on some kinds of oak. In general, one species or kind is grafted on the same species, as apple on apple, pear on pear, orange on orange.

*The forming, growing tissue of the stem (on the plants we have been discussing) is the **cambium** (Chap. X), lying on the outside of the woody cylinder beneath the bark. In order that union may take place, the cambium of the scion and of the stock must come together. Therefore the scion is set in the side of the stock. There are many ways of shaping the scion and of preparing the stock to receive it. These ways are dictated largely by the relative sizes of scion and stock, although many of them are matters of personal preference. The underlying principles are two: securing *close contact* between the cambiums of scion and stock; *covering the wounded surfaces* to prevent evaporation and to protect the parts from disease.*

\* On large stocks the commonest form of grafting is the **cleft-graft**. The stock is cut off and split; and in one or both sides a wedge-shaped scion is firmly inserted. Fig. 165 shows the scion; Fig. 166, the scions set in the stock; Fig. 167, the stock waxed. It will be seen that the lower bud—that lying in the wedge—is covered by the wax; but being nearest the food supply and least exposed to weather, it is the most likely to grow: it will push through the wax.

**Cleft-grafting** is practised in spring, as growth begins. The scions are cut previously, when perfectly dormant, and from the tree which it is desired to propagate. The scions are kept in sand or moss in the cellar. Limbs of various

sizes may be cleft-grafted,—from a half inch up to four inches in diameter; but a diameter of one to one and a half inches is the most convenient size. All the leading or main branches of a tree top may be grafted. If the remaining parts of the top are gradually cut away and the scions grow well, the entire top will be changed over to the new variety.



FIG. 165.—  
SCION OF  
APPLE.

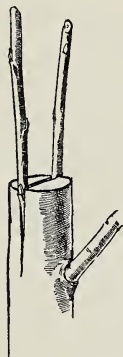


FIG. 166.—THE  
SCION INSERTED.



FIG. 167.—THE  
PARTS WAXED.

Another form of grafting is known as **budding**. In this case a single bud is used, and it is slipped underneath the bark of the stock and securely tied (not waxed) with soft material, as bass bark, corn shuck, yarn, or raffia (the last a commercial palm fibre). Budding is performed *when the bark of the stock will slip or peel* (so that the bud can be inserted), and *when the bud is mature enough to grow*. Usually budding is performed in late summer or early fall, when the winter buds are well formed; or it may be practised in spring with buds cut in winter. In ordinary summer budding (which is the usual mode) the “bud” or scion forms a union with the stock, and then lies dormant till the following spring, as if it were still on its own twig.

Budding is mostly restricted to young trees in the nursery. In the spring following the budding, the stock is cut off just above the bud, so that only the shoot from the bud grows to make the future tree. This prevailing form of

budding (shield-budding) is shown in Fig. 168.



FIG. 168. — BUD-  
DING. The  
"bud"; the  
opening to re-  
ceive it; the  
bud tied.

SUGGESTIONS. — 128. Name the plants that the gardener propagates by means of cuttings. 129. By means of grafts. 130. The cutting-box may be set in the window. If the box does not receive direct sunlight, it may be covered with a pane of glass to prevent evaporation. Take care that the air is not kept too close, else the damping-off fungi may attack the cuttings, and they will rot at the surface of the ground. See that the pane is raised a little at one end to afford ventilation; and if the water collects in drops on the under side of the glass, remove the pane for a time. 131. Grafting wax is made of beeswax, resin, and tallow. A good recipe is one part (as one pound) of rendered tallow, two parts of beeswax, four parts of resin; melt together in a kettle; pour the liquid into a pail or tub of water to solidify it; work with the hands until it has the colour and "grain" of taffy candy, the hands being greased when necessary. The wax will keep any length of time. For the little grafting that any pupil would do, it is better to buy the wax of a seedsman. 132. Grafting is hardly to be recommended as a general school diversion, as the making of cuttings is; and the account of it in this chapter is inserted chiefly to satisfy the general curiosity on the subject. 133. In Chap. V we had a definition of a plant generation: what is "one generation" of a grafted fruit tree, as Le Conte pear, Baldwin, or Ben Davis apple? 134. The Elberta peach originated about 1880: what is meant by "originated"? 135. How is the grape propagated so as to come true to name (explain what is meant by "coming true")? currant? strawberry? raspberry? blackberry? peach? pear? orange? fig? plum? cherry? apple? chestnut? pecan?

## CHAPTER XVII

### HOW PLANTS CLIMB

WE have found that plants struggle or contend for a place in which to live. Some of them become adapted to grow in the forest shade, others to grow on other plants, as epiphytes, others to *climb to the light*. Observe how woods grapes, and other forest climbers, spread their foliage on the very top of the forest tree, while their long flexible trunks may be bare.

There are several ways by which plants climb, but most climbers may be classified into four groups : (1) **scramblers**, (2) **root climbers**, (3) **tendrill climbers**, (4) **twiners**.

**Scramblers.** — Some plants rise to light and air *by resting their long and weak stems on the tops of bushes and quick-growing herbs*. Their stems may be elevated in part by the growing twigs of the plants on which they recline. Such plants are scramblers. Usually they are provided with prickles or bristles. In most weedy swamp thickets, scrambling plants may be found. Briers, some roses, bed-straw or galium, bittersweet (*Solanum Dulcamara*, not the *Celastrus*), the tear-thumb polygonums, and other plants are familiar examples of scramblers.

**Root Climbers.** — Some plants climb by means of *true roots*. These roots seek the dark places and therefore enter the chinks in walls and bark. The trumpet creeper is a familiar example (Fig. 36). The true or English ivy, which is often grown to cover buildings, is another instance. Still another is the poison ivy. Roots are

distinguished from stem tendrils by their *irregular or indefinite position* as well as by their mode of growth.

**Tendrils.** — A slender coiling part that serves to hold a climbing plant to a support is known as a **tendrils**.



FIG. 169. — TENDRIL, to show where the coil is changed.

The free end swings or curves until it strikes some object, when it attaches itself and then coils and *draws the plant close to the support*. The spring of the coil also allows the plant *to move in the wind*, thereby enabling the

plant to maintain its hold. Slowly pull a well-matured tendril from its support, and note how strongly it holds on. Watch the tendrils in a wind-storm. Usually the tendril attaches to the support by *coiling about it*, but the Virginia creeper and the Boston ivy (Fig. 170) attach to walls by means of *disks* on the ends of the tendrils.

Since both ends of the tendril are fixed, when it finds a support, the coiling would tend to twist it in two. It will be found, however, that the tendril *coils in different di-*

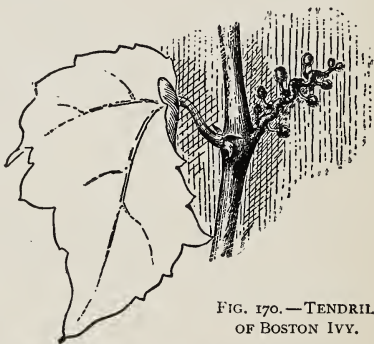


FIG. 170. — TENDRIL OF BOSTON IVY.

*rections* in different parts of its length. In Fig. 169, showing an old and stretched-out tendril, the change of direction in the coil occurred at *a*. In long tendrils of cucumbers and melons there may be several changes of direction.

Tendrils may represent either *branches or leaves*. In the



Virginia creeper and the grape they are branches; they stand opposite the leaves in the position of fruit clusters, and sometimes one branch of a fruit cluster is a tendril. These tendrils are therefore homologous with fruit-clusters, and fruit clusters are branches.

In some plants tendrils are *leaflets* (Chap. XI). Examples are the sweet pea and the common garden pea. In Fig. 171, observe the leaf with its two great stipules, petiole, six normal leaflets, and two or three pairs of leaflet tendrils and a terminal leaflet tendril. The cobeia, a common garden climber, has a similar arrangement. In some cases tendrils are *stipules*, as probably in the green briers (*smilax*).

The *petiole* or *midrib* may act as a *tendril*, as in various kinds of clematis. In Fig. 172, the common wild clematis or "old man vine," this mode is seen.

**Twiners.** — The entire plant or shoot may wind about a support. Such a plant is a **twiner**. Examples are bean, hop, morning-glory, moon-flower, false bittersweet or waxwork (*Celastrus*), some honeysuckles, wistaria, Dutchman's pipe, dodder. The free tip of the twining branch *sweeps about in curves*, much as the tendril does, until it finds support or becomes old and rigid.

Each kind of plant usually coils *in only one direction*. Most plants coil against the sun, or from the observer's left across his front to his right as he faces the plant.

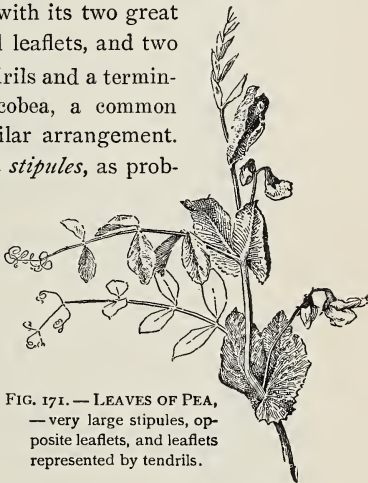


FIG. 171. — LEAVES OF PEA,  
— very large stipules, op-  
posite leaflets, and leaflets  
represented by tendrils.

Examples are bean, morning-glory. The hop twines from the observer's right to his left, or with the sun.

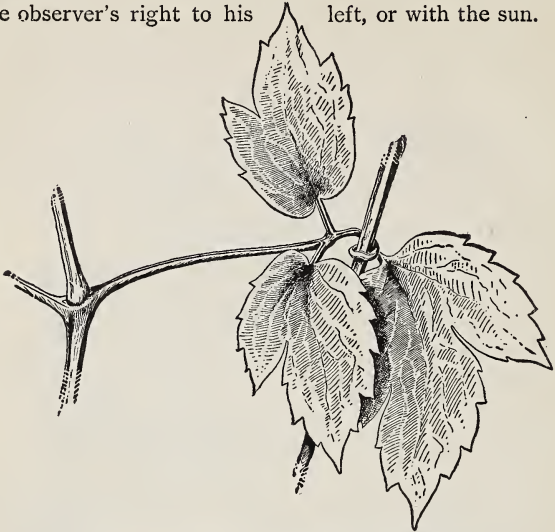


FIG. 172. — CLEMATIS CLIMBING BY LEAF-TENDRIL.

**SUGGESTIONS.—136.** Set the pupil to watch the behaviour of any plant that has tendrils at different stages of maturity. A vigorous cucumber plant is one of the best. Just beyond the point of a young straight tendril set a stake to compare the position of it. Note whether the tendril changes position from hour to hour or day to day. **137.** Is the tip of the tendril perfectly straight? Why? Set a small stake at the end of a strong straight tendril, so that the tendril will just reach it. Watch and make drawing. **138.** If a tendril does not find a support what does it do? **139.** To test the movement of a free tendril draw an ink line lengthwise of it, and note whether the line remains always on the concave side or the convex side. **140.** Name the tendril-bearing plants that you know. **141.** Make similar observations and experiments on the tips of twining stems. **142.** What twining plants do you know, and which way do they twine? **143.** How does any plant that you know shoot up? **144.** Does the stem of a climbing plant contain more or less substance (weight) than an erect self-supporting stem of the same height? Explain,

## CHAPTER XVIII

### THE FLOWER—ITS PARTS AND FORMS

THE function of the flower is to *produce seed*. It is probable that all its varied forms and colours contribute to this supreme end. These forms and colours please the human fancy and add to the joy of living, but the flower exists for the good of the plant, not for the good of man. The parts of the flower are of two general kinds—those that are directly concerned in the *production of seeds*, and those that act as *covering and protecting organs*. The former parts are known as the **essential organs**; the latter as the **floral envelopes**.

**Envelopes.**—The floral envelopes usually bear a close resemblance to leaves. These envelopes are very commonly of two series or kinds—the *outer* and the *inner*. The outer series, known as the **calyx**, is usually smaller and green. It usually comprises the outer cover of the flower bud. The calyx is the lowest whorl in Fig. 173.

The inner series, known as the **corolla**, is usually coloured and more special or irregular in shape than the calyx. It is the showy part of the flower, as a rule. The corolla is the second or large whorl in Fig. 173.

The *calyx* may be composed of several leaves. Each leaf is a **sepal**. If it is of one piece, it may be lobed or divided, in which case the divisions are called **calyx-lobes**.



FIG. 173.—FLOWER OF A BUTTERCUP IN SECTION.

In like manner, the corolla may be composed of **petals**, or it may be of one piece and variously lobed. A calyx of one piece, no matter how deeply lobed, is **gamosepalous**. A corolla of one piece is **gamopetalous**. When these series are of separate pieces, as in Fig. 173, the flower is said to be **polysepalous** and **polypetalous**. Sometimes both

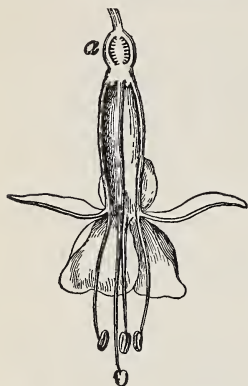


FIG. 174. — FLOWER OF FUCHSIA IN SECTION.

series are of separate parts, and sometimes only one of them is so formed.

*The floral envelopes are homologous with leaves.* Sepals and petals, at least when more than three or five, are in more than one whorl, and one whorl stands below another so that the parts overlap. They are borne on the expanded or thickened end of the flower stalk; this end is the **torus**. In Fig. 173 all the parts are seen as attached to the torus. This part is sometimes called the *re-*

*ceptacle*, but this word is a common-language term of several meanings, whereas torus has no other meaning. Sometimes one part is attached to another part, as in the fuchsia (Fig. 174), in which the petals are borne on the calyx-tube.

**Subtending Parts.** — Sometimes there are *leaf-like parts just below the calyx*, looking like a second calyx. Such parts accompany the carnation flower. These parts are **bracts** (bracts are small specialized leaves); and they form an **involucre**. We must be careful that we do not mistake them for true flower parts. Sometimes the bracts are large and petal-like, as in the great white blooms of the

flowering dogwood: here the real flowers are several, small and greenish, forming a small cluster in the centre.

**Essential Organs.**—The essential organs are of two series. The outer series is composed of the stamens. The inner series is composed of the pistils.

*Stamens* bear the pollen, which is made up of grains or spores, each spore usually being a single plant cell. The stamen is of two parts, as is readily seen in Figs. 173, 174,—the enlarged terminal part or **anther**, and the stalk or **filament**. The filament is often so short as to seem to be absent, and the anther is then said to be *sessile*. The anther bears the pollen spores. It is made up of two or four parts (known as **sporangia** or **spore-cases**), which burst and discharge the pollen. *When the pollen is shed, the stamen dies.*

The *pistil* has three parts: the lowest, or seed-bearing part, which is the **ovary**; the **stigma** at the upper extremity, which is a flattened or expanded surface, and usually roughened or sticky; the stalk-like part or **style**, connecting the ovary and the stigma. Sometimes the style is apparently wanting, and the stigma is said to be *sessile* on the ovary. These parts are shown in the fuchsia (Fig. 174). The ovary or seed vessel is at *a*. A long style, bearing a large stigma, projects from the flower. See also Figs. 175 and 176.

Stamens and pistils probably are homologous with leaves. A pistil is sometimes conceived to represent anciently a

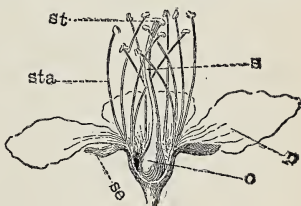


FIG. 175.—THE STRUCTURE OF A PLUM BLOSSOM.

*se*, sepals; *p*, petals; *sta*, stamens; *o*, ovary; *s*, style; *st*, stigma. The pistil consists of the ovary, the style and the stigma. It contains the seed part. The stamens are tipped with anthers, in which the pollen is borne. The ovary, *o*, ripens into the fruit.

leaf as if rolled into a tube; and an anther, a leaf of which the edges may have been turned in on the midrib.



FIG. 176. — SIMPLE PISTILS OF BUTTERCUP, one in longitudinal section.

The pistil may be of *one part or compartment, or of many parts*. The different units or parts of which it is composed are **carpels**. Each carpel is homologous with a leaf. Each carpel bears one or more seeds. A pistil of one carpel is **simple**; of two or more carpels, **compound**. Usually the structure of the pistil may be de-

termined by cutting horizontally across the lower or seed-bearing part, as Figs. 177, 178 explain. A flower may contain a simple pistil (one carpel), as the pea (Fig. 177); *several simple pistils* (several separate carpels), as the buttercup (Fig. 176); or a *compound pistil* with carpels united, as the Saint John's wort (Fig. 178) and apple. How many carpels in an apple? A peach? An okra pod? A bean pod? The seed cavity in each carpel is called a **locule** (Latin *locus*, a place). In these *locules the seeds are borne*.



FIG. 177. — PISTIL OF GARDEN PEA, the stamens being pulled down in order to disclose it; also a section showing the single compartment (compare Fig. 188).



FIG. 178. — COMPOUND PISTIL OF A ST. JOHN'S WORT. It has 5 carpels.

**Conformation of the Flower.** — A flower that has calyx, corolla, stamens, and pistils is said to be **complete** (Fig. 173); all others are **incomplete**. In some flowers both the floral envelopes are wanting: such are **naked**. When one of the floral envelope series is wanting, the remaining series is said to be calyx, and the flower is therefore **apetalous** (without petals). The knot-



weed (Fig. 179), smartweed, buckwheat, elm are examples.

Some flowers lack the pistils: these are **staminate**, whether the envelopes are missing or not.

Others lack the stamens: these are **pistillate**.

Others have neither stamens nor pistils: these are **sterile** (snowball and hydrangea). Those

that have both stamens and pistils are **perfect**, whether or not the envelopes are missing.

Those that lack either stamens or pistils are **imperfect** or **diclinous**. Staminate and pistillate flowers are imperfect or diclinous.

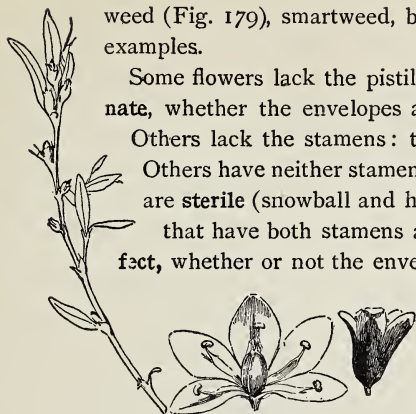


FIG. 179.—KNOTWEED, a very common but inconspicuous plant along hard walks and roads. Two flowers, enlarged, are shown at the right. These flowers are very small and borne in the axils of the leaves.

When staminate and pistillate flowers are borne on the same plant, *e.g.* oak (Fig. 180), corn, beech, chestnut, hazel, walnut, hickory, pine, begonia (Fig. 181), watermelon,



FIG. 180.—STAMINATE CATKINS OF OAK. The pistillate flowers are in the leaf axils, and not shown in this picture.



FIG. 181.—BEGONIA FLOWERS.

Staminate at A; pistillate below, with the winged ovary at B.

gourd, pumpkin, the plant is **monœcious** ("in one house"). When they are on different plants, *e.g.* poplar, cottonwood,



FIG. 182. — CATKINS OF A WILLOW.

A staminate flower is shown at *s*, and a pistillate flower at *p*. The staminate and pistillate are on different plants.

bois d'arc, willow (Fig. 182), the plant is **diœcious** ("in two houses"). Some varieties of strawberry, grape, and mulberry are partly diœcious. Is the rose either monœcious or diœcious?

Flowers in which the parts of each series are alike are said to be **regular** (as in Figs. 173, 174, 175). Those in which some parts are unlike other parts of the same series

are **irregular**. Their regularity may be in calyx, as in nasturtium (Fig. 183); in corolla (Figs. 184, 185); in the stamens (compare nasturtium, catnip, Fig. 185, sage); in the pistils. Irregularity is most frequent in the corolla.



FIG. 183. — FLOWER OF GARDEN NASTURTIUM.

Separate petal at *a*. The calyx is produced into a spur.

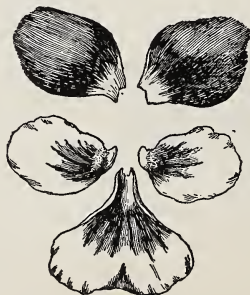


FIG. 184. — THE FIVE PETALS OF THE PANSY, detached to show the form.



FIG. 185. — FLOWER OF CATNIP.

**Various Forms of Corolla.**—The corolla often assumes very definite or distinct forms, especially when gamopetalous. It may have a long tube with a wide-flaring limb, when it is said to be **funnelform**, as in morning-glory and pumpkin. If the tube is very narrow and the limb stands at right angles to it, the corolla is **salverform**, as in phlox. If the tube is very short and the limb wide-spreading and nearly circular in outline, the corolla is **rotate** or **wheel-shaped**, as in potato.

A gamopetalous corolla or gamosepalous calyx is often cleft in such way as to make two prominent parts. Such parts are said to be **lipped** or **labiate**. Each of the lips or lobes may be notched or toothed. In 5-membered flowers, the lower lip is usually 3-lobed and the upper one 2-lobed. Labiate flowers are characteristic of the mint family (Fig. 185), and the family therefore is called the Labiatae. (Literally, labiate means merely "lipped," without specifying the number of lips or lobes; but it is commonly used to designate 2-lipped flowers.) Strongly 2-parted polypetalous flowers may be said to be labiate; but the term is oftenest used for gamopetalous corollas.

Labiate gamopetalous flowers that are closed in the throat (or entrance to the tube) are said to be **grinning** or **personate** (personate means *masked*). Snapdragon is a typical example; also toadflax or butter-and-eggs (Fig. 186), and many related plants. Personate flowers usually have definite relations to insect pollination. Observe how an insect forces his head into the closed throat of the toadflax.



FIG. 186.—PERSONATE FLOWER OF TOADFLAX.

The peculiar flowers of the pea tribes are explained in Figs. 187, 188.

**Spathe Flowers.**—In many plants, very simple (often naked) flowers are borne in dense, more or less fleshy spikes, and the spike is inclosed in or attended by a leaf, sometimes corolla-like, known as a **spathe**. The spike of flowers is technically known as a **spadix**. This type of flower is characteristic of the great arum family, which is



FIG. 187.—FLOWERS OF THE COMMON BEAN, with one flower opened (*a*) to show the structure.

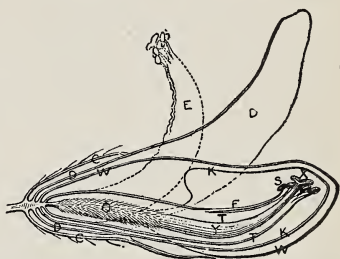


FIG. 188.—DIAGRAM OF ALFALFA FLOWER IN SECTION:

*C*, calyx, *D*, standard; *W*, wing; *K*, keel; *T*, stamen-tube; *F*, filament of tenth stamen; *X*, stigma; *Y*, style; *O*, ovary; the dotted lines at *E* show position of stamen-tube, when pushed upward by insects. Enlarged.

chiefly tropical. The commonest wild representatives are Jack-in-the-pulpit, or Indian turnip, and skunk cabbage. In the former the flowers are all diclinous and naked. In the skunk cabbage all the flowers are perfect and have four sepals. The common calla is a good example of this type of inflorescence.

**Composite Flowers.**—The head (anthodium) or so-called “flower” of sunflower (Fig. 189), thistle, aster, dandelion, daisy, chrysanthemum, goldenrod, is composed of several or many little flowers, or florets. These

florets are inclosed in a more or less dense and usually green *involucre*. In the thistle (Fig. 190) this involucre is prickly. A longitudinal section discloses the florets, all attached at bottom to a common torus, and densely packed in the involucre. The pink tips of these florets constitute the showy part of the head.



FIG. 189. — HEAD OF SUNFLOWER.

Each floret of the thistle (Fig. 190) is a complete flower. At *a* is the ovary. At *b* is a much-divided plummy calyx, known as the *pappus*. The corolla is long-tubed, rising above the pappus, and is enlarged and 5-lobed

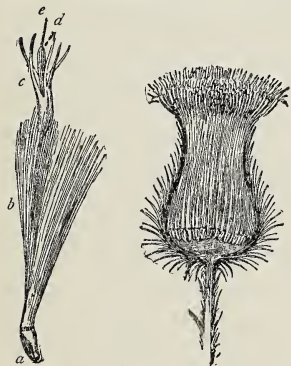


FIG. 190. — LONGITUDINAL SECTION OF THISTLE HEAD; also a FLORET OF THISTLE.

at the top, *c*. The style projects at *e*. The five anthers are united about the style in a ring at *d*. Such anthers are said to be *syngenesious*. These are the various parts of the florets of the *Compositæ*. In some cases the pappus is in the form of barbs, bristles, or scales, and sometimes it is wanting. The pappus, as we shall see later, assists in distributing the seed. Often the florets are not all alike. The corolla

of those in the outer circles may be developed into a *long, straplike, or tubular part*, and the head then has the ap-

pearance of being one flower with a border of petals. Of such is the sunflower (Fig. 189), aster, bachelor's button or cornflower, and field daisy (Fig. 211). These long corolla-limbs are called **rays**. In some cultivated composites, all the florets may develop rays, as in the dahlia and the chrysanthemum. In some species, as dandelion, all the florets naturally have rays. Syngenesious arrangement of anthers is the most characteristic single feature of the composites.

**Double Flowers.** — Under the stimulus of cultivation and increased food supply, flowers tend to become double.



FIG. 191. — PETALS ARISING FROM THE STAMINAL COLUMN OF HOLLYHOCK, and accessory petals in the corolla-whorl.

True doubling arises in two ways, morphologically: (1) *stamens or pistils may produce petals* (Fig. 191); (2) *adventitious or accessory petals may arise in the circle of petals*. Both these categories may be present in the same flower. In the full

double hollyhock the petals derived from the staminal column are shorter and make a rosette in the centre of the flower. In Fig. 192 is shown the doubling of a daffodil by the modification of stamens. Other modifications of flowers are sometimes known as doubling. For example, double dahlias, chrysanthemums, and sunflowers are forms in which the disk flowers have developed rays. The snowball is another case. In the wild snowball the external flowers of the cluster are large and sterile. In the culti-



vated plant all the flowers have become large and sterile. Hydrangea is a similar case.



FIG. 192. — NARCISSUS OR DAFFODIL. Single flower at the right.

**SUGGESTIONS.—145.** If the pupil has been skilfully conducted through this chapter *by means of careful study of specimens* rather than as a mere memorizing process, he will be in mood to challenge any flower that he sees and to make an effort to understand it. Flowers are endlessly modified in form; but they can be understood if the pupil looks first for the anthers and ovaries. How may anthers and ovaries always be distinguished? **146.** It is excellent practice to find the flowers in plants that are commonly known by name, and to determine the main points in their structure. What are the flowers in Indian corn? pumpkin or squash? celery? cabbage? potato? pea? tomato? okra? cotton? rhubarb? chestnut? wheat? oats? **147.** Do all forest trees have flowers? Explain. **148.** Name all the monœcious plants you know. Diccious. **149.** What plants do you know that bloom before the leaves appear? Do any bloom after the leaves fall? **150.** Explain the flowers of marigold, hyacinth, lettuce, clover, asparagus, garden calla, aster, locust, onion, burdock, lily-of-the-valley, crocus, Golden Glow, rudbeckia, cowpea. **151.** Define a *flower*.

**NOTE TO THE TEACHER.—**It cannot be urged too often that *the specimens themselves* be studied. If this chapter becomes a mere recitation on names and definitions, the exercise will be worse than useless. Properly taught by means of the flowers themselves, the names become merely incidental and a part of the pupil's language, and the subject has *living interest*.

## CHAPTER XIX

### THE FLOWER—FERTILIZATION AND POLLINATION

**Fertilization.**—*Seeds result from the union of two elements or parts.* One of these elements is a cell-nucleus

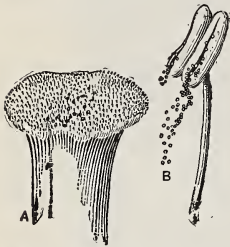


FIG. 193. — *B*, POLLEN escaping from anther; *A*, pollen germinating on a stigma. Enlarged.

of the pollen-grain. The other element is the cell-nucleus of an egg-cell, borne in the ovary. The pollen-grain falls on the stigma (Fig. 193). It absorbs the juices exuded by the stigma, and grows by sending out a tube (Fig. 194). This tube grows downward through the style, absorbing food as it goes, and finally reaches the egg-cell in the interior of an ovule in the ovary (Fig. 195), and **fertilization**,

or union of a nucleus of the pollen and the nucleus of the egg-cell in the ovule, takes place. *The ovule and embryo within then develops into a seed.* The growth of the pollen-tube is often spoken of as germination of the pollen, but it is not germination in the sense in which the word is used when speaking of seeds.

Better seeds—that is, those that produce stronger and more fruitful plants—often result when the *pollen comes from another flower*. Fertilization effected between different flowers is **cross-fertilization**; that resulting from the



FIG. 194. — A POLLEN-GRAIN AND THE GROWING TUBE.

application of pollen to pistils in the same flower is close-fertilization or self-fertilization. It will be seen that the cross-fertilization relationship may be of many degrees—between two flowers in the same cluster, between those in different clusters on the same branch, between those on different plants. Usually fertilization takes place only between plants of the same species or kind.

In many cases there is, in effect, an *apparent selection of pollen* when pollen from two or more sources is applied to the stigma. Sometimes the foreign pollen, if from the same kind of plant, grows, and fertilization results, while pollen from the same flower is less promptly effective. If, however, no foreign pollen is present, the pollen from the same flower may finally serve the same purpose.

In order that the pollen may grow, *the stigma must be ripe*. At this stage the stigma is usually moist and sometimes sticky. A ripe stigma is said to be **receptive**. The stigma may remain receptive for several hours or even days, depending on the kind of plant, the weather, and how soon pollen is received. Watch a certain flower every day to see the anther locules open and the stigma ripen. When fertilization takes place, the stigma dies. Observe, also, how soon the petals wither after the stigma has received pollen.

**Pollination.**—The transfer of the pollen from anther to stigma is known as **pollination**. The pollen may

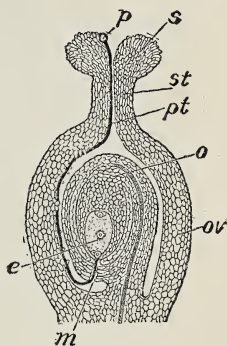


FIG. 195. — DIAGRAM TO REPRESENT FERTILIZATION.

s, stigma; st, style; ov, ovary; o, ovule; p, pollen-grain; pt, pollen-tube; e, egg-cell; m, micropyle.

fall of its own weight on the adjacent stigma, or it may be carried from flower to flower by wind, insects, or other agents. There may be **self-pollination** or **cross-pollination**, and of course it must always precede fertilization.



FIG. 196. —  
ANTHER OF  
AZALEA,  
opening by  
terminal  
pores.

Usually the pollen is discharged by the bursting of the anthers. The commonest method of discharge is through a *slit* on either side of the anther (Fig. 193). Sometimes it discharges through a *pore* at the apex, as in azalea (Fig. 196), rhododendron, huckleberry, wintergreen.

In some plants a part of the anther wall raises or falls as a *lid*, as in barberry (Fig. 197), blue cohosh, May apple. The opening of an anther

(as also of a seed-pod) is known as **dehiscence** (*de*, from; *hisco*, to gape). When an anther or seed pod opens, it is said to *dehisce*.

*Most flowers are so constructed as to increase the chances of cross-pollination.* We have seen that the stigma may have the power of choosing foreign pollen. The commonest means of necessitating cross-pollination is the *different times of maturing of stamens and pistils in the same flower*. In most cases the stamens mature first: the flower is then **proterandrous**. When the pistils mature first, the flower is **proterogynous**. (*Aner*, *andr*, is a Greek root often used, in combinations, for stamens, and *gyne* for pistil.) The difference in time of ripening may be an hour or two, or it may be a day. The ripening of the stamens and the pistils at different times is known as **dichogamy**, and flowers of such character are said to be dichogamous. There is little chance for dichogamous flowers to pollinate themselves. Many flowers are *imperfectly dichogamous*—



FIG. 197. —  
BARBERRY  
STAMEN,  
with anther  
opening by  
lids.

some of the anthers mature simultaneously with the pistils, so that there is chance for self-pollination in case foreign pollen does not arrive. Even when the stigma receives pollen from its own flower, cross-fertilization may result. The hollyhock is proterandrous. Fig. 198 shows a flower recently



FIG. 198.—FLOWER OF HOLLYHOCK; proterandrous.

expanded. The centre is occupied by the column of stamens. In Fig. 199, showing an older flower, the long styles are conspicuous.

*Some flowers are so constructed as to prohibit self-pollination.* Very irregular flowers are usually of this kind.



FIG. 199.—OLDER FLOWER OF HOLLYHOCK.

With some of them, the petals form a sac to inclose the anthers and the pollen cannot be shed on the stigma but is retained until a bee forces the sac open; the pollen is rubbed on the hairs of the bee and transported.

Regular flowers usually depend mostly on dichogamy and the selective power of the pistil to insure crossing *Flowers that are very*

*irregular and provided with nectar and strong perfume are usually pollinated by insects.* Gaudy colours probably attract insects in many cases, but perfume appears to be a greater attraction.



FIG. 200. — FLOWER OF LARKSPUR.

The insect *visits the flower for the nectar* (for the making of honey) *and may unknowingly carry the pollen.* Spurs and sacs in the flower are **nectaries** (Fig. 200), but in spurless flowers the nectar is usually secreted *in the bottom of the flower cup.* This compels the insect to pass by the anther and rub against the pollen before it reaches the nectar. Sometimes the anther is a

long lever poised on the middle point and the insect bumps against one end and lifts it, thus bringing the other end of the lever with the pollen sacs down on its back. Flowers that are pollinated by insects are said to be **entomophilous** ("insect loving"). Fig. 200 shows a larkspur. The envelopes are separated in Fig. 201. The long spur at once suggests insect pollination. The spur is a sepal. Two hollow petals project into this spur, apparently serving to guide the bee's tongue. The two smaller petals, in front, are peculiarly coloured and perhaps serve the bee in locating the nectary. The stamens ensheath the pistils (Fig. 202). As the insect stands on the flower and thrusts its head into the centre,

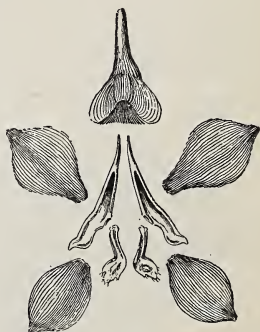


FIG. 201. — ENVELOPES OF A LARKSPUR. There are five wide sepals, the upper one being spurred. There are four small petals.



the envelopes are pushed downward and outward and the pistil and stamens come in contact with its abdomen. Since the flower is proterandrous, the pollen that the pistils receive from the bee's abdomen must come from another flower. Note a somewhat similar arrangement in the toadflax or butter-and-eggs.

In some cases (Fig. 203) the stamens are longer than the pistil in one flower and shorter in another. If the insect visits such flowers, it gets pollen on its head from the long-stamen flower, and deposits this pollen on the stigma in the long-pistil flower. Such flowers are **dimorphous** (of two forms). If pollen from its own flower and from another flower both fall on the stigma, the probabilities are that the stigma will choose the foreign pollen.



FIG. 202. — STAMENS OF LARKSPUR, surrounding the pistils.

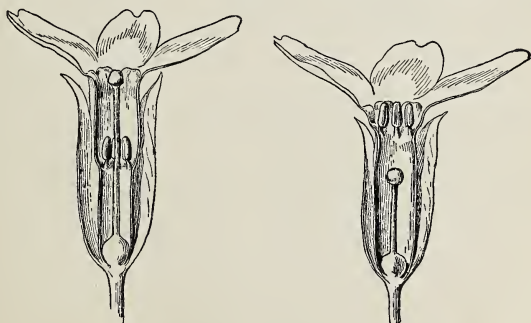


FIG. 203. — DIMORPHIC FLOWERS OF PRIMROSE.

*Many flowers are pollinated by the wind.* They are said to be **anemophilous** ("wind loving"). Such flowers pro-

duce great quantities of pollen, for much of it is wasted. They usually have broad stigmas, which expose large surfaces to the wind. They are usually lacking in gaudy colours and in perfume. Grasses and pine trees are typical examples of anemophilous plants.

In many cases cross-pollination is assured because the *stamens and the pistils are in different flowers* (diclinous).



FIG. 204. — FLOWERS OF BLACK WALNUT: two pistillate flowers at A, and staminate catkins at B.

Monœcious and dioecious plants may be pollinated by wind or insects, or other agents (Fig. 204). They are usually wind-pollinated, although willows are often, if not mostly, insect-pollinated. The Indian corn is a monœcious plant. The staminate flowers are in a terminal panicle

(tassel). The pistillate flowers are in a dense spike (ear), inclosed in a sheath or husk. Each "silk" is a style. Each pistillate flower produces a kernel of corn. Sometimes a few pistillate flowers are borne in the tassel and a few staminate flowers on the tip of the ear. Is self-fertilization possible with the corn? Why does a "volunteer" stalk standing alone in a garden have only a few grains on the ear? What is the direction of the prevailing wind in summer? If only two or three rows of corn are

planted in a garden where prevailing winds occur, in which direction had they better run?

Although most flowers are of such character as to insure or increase the chances of cross-pollination, there are some *that absolutely forbid crossing*. These flowers are usually

borne beneath or on the ground, and they lack showy colours and perfumes. They are known as **cleistogamous** flowers (meaning self-fertilizing flowers). The plant has normal showy flowers that may be insect-pollinated, and in addition is provided with these simplified flowers. Only a few plants bear cleistogamous flowers. Hog-peanut, common blue violet, fringed winter-green, and dalibarda are

the best subjects in this country. Fig. 205 shows a cleistogamous flower of the blue violet at *a*. Above the



FIG. 205.—COMMON BLUE VIOLET. The familiar flowers are shown, natural size. The corolla is spurred. Late in the season, cleistogamous flowers are often borne on the surface of the ground. A small one is shown at *a*. A nearly mature pod is shown at *b*. Both *a* and *b* are one third natural size.

true roots, slender stems bear these flowers, that are provided with a calyx, and a curving corolla which does not open. Inside are the stamens and the pistils. Late in the season the cleistogamous flowers may be found just underneath the mould. They never rise above ground. The following summer one may find a seedling plant, in

some kinds of plants, with the remains of the old cleistogamous flower still adhering to the root. Cleistogamous flowers usually appear after the showy flowers have



FIG. 206. — PODS OF PEANUTS RIPENING UNDERGROUND.

passed. They seem to insure a crop of seed by a method that expends little of the plant's energy. The pupil will be interested to work out the fruiting of the pea-



FIG. 207. — STRUGGLE FOR EXISTENCE AMONG THE APPLE FLOWERS.

nut (Fig. 206). Unbaked fresh peanuts grow readily and can easily be raised in Canada. in a warm sandy garden.

SUGGESTIONS. —

152. *Not all the flowers produce seeds.* Note that an apple tree may bloom very full, but that only relatively few apples

may result (Fig. 207). *More pollen is produced than is needed to fertilize the flowers;* this increases the chances that sufficient

stigmas will receive acceptable pollen to enable the plant to perpetuate its kind. At any time in summer, or even in fall, examine the apple trees carefully to determine whether any dead flowers or flower stalks still remain about the apple; or, examine any full-blooming plant to see whether any of the flowers fail.

**153.** Keep watch on any plant to see whether insects visit it. What kind? When? What for? **154.** Determine whether the calyx serves any purpose in protecting the flower. Very carefully remove the calyx from a bud that is normally exposed to heat and sun and rain, and see whether the flower then fares as well as others. **155.** Cover a single flower on its plant with a tiny paper or muslin bag so tightly that no insect can get in. If the flower sets fruit, what do you conclude? **156.** Remove carefully the corolla from a flower nearly ready to open, preferably one that has no other flowers very close to it. Watch for insects. **157.** Find the nectar in any flower that you study. **158.** Remove the stigma. What happens? **159.** Which of the following plants have perfect flowers: pea, bean, pumpkin, cotton, clover, buckwheat, potato, Indian corn, peach, chestnut, hickory, watermelon, sunflower, cabbage, rose, begonia, geranium, cucumber, calla, willow, cottonwood, cantaloupe? What have the others? **160.** On wind-pollinated plants, are either anthers or stigmas more numerous? **161.** Are very small coloured flowers usually borne singly or in clusters? **162.** Why do rains at blooming time often lessen the fruit crop? **163.** Of what value are bees in orchards? **164.** *The crossing of plants to improve varieties or to obtain new varieties.*—It may be desired to perform the operation of pollination by hand. In order to insure the most definite results, every effort should be made rightly to apply the pollen which it is desired shall be used, and rigidly to exclude all other pollen. (a) The first requisite is to remove the anthers from the flower which it is proposed to cross, and they *must be removed before the pollen has been shed*. The flower-bud is therefore opened and the anthers taken out. Cut off the floral envelopes with small, sharp-pointed scissors, then cut out or pull out the anthers, leaving only the pistil untouched; or merely open the corolla at the end and pull out the anthers with a hook or tweezers; and this method is often the best one. It is best to delay the operation as long as possible and yet not allow the bud to open (and thereby expose the flower to foreign pollen) nor the anthers to discharge the pollen. (b) The flower *must next be covered with a paper bag to prevent the access of pollen* (Figs. 208, 209). If the stigma is not receptive at the time (as it usually is not), the desired pollen is not applied at once. The bag may be removed from time to time to allow of examination of the pistil, and when the stigma is mature, which is told by its glutinous or roughened appearance,

the time for pollination has come. If the bag is slightly moistened, it can be puckered more tightly about the stem of the plant. The time required for the stigma to mature varies from several hours to a few days. (c) When the stigma is ready, an unopened anther from the desired flower is crushed on the finger nail or a knife blade, and the pollen is rubbed on the stigma by means of a tiny brush, the point of a knife blade, or a sliver of wood. The



FIG. 208.—A PAPER BAG,  
with string inserted.



FIG. 209.—THE BAG TIED  
OVER A FLOWER.

flower is *again covered with the bag*, which is allowed to remain for several days until all danger of other pollination is past. Care must be taken completely to cover the stigmatic surface with pollen, if possible. The seeds produced by a crossed flower produce *hybrids*, or plants having parents belonging to different varieties or species. 165. One of the means of securing new forms of plants is by making hybrids. Why?

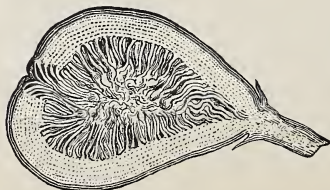


FIG. 210.—The fig is a hollow torus with flowers borne on the inside,  
and pollinated by insects that enter at the apex.



## CHAPTER XX

### FLOWER-CLUSTERS

**Origin of the Flower-cluster.** — We have seen that branches arise from the axils of leaves. Sometimes the leaves may be reduced to bracts and yet branches are borne in their axils. Some of the branches grow into long limbs; others become short spurs; *others bear flowers*. In fact, a flower is itself a specialized branch.

Flowers are usually borne near the top of the plant. Often they are produced in great numbers. It results, therefore, that flower branches usually stand close together, forming a **cluster**. The shape and the arrangement of the flower-cluster *differ with the kind of plant*, since each plant has its own mode of branching.

Certain definite or well-marked types of flower-clusters have received names. Some of these names we shall discuss, but the flower-clusters that perfectly match the definitions are the exception rather than the rule. The determining of the



FIG. 211. — TERMINAL FLOWERS OF THE WHITEWEED (in some places called ox-eye daisy).

kinds of flower-clusters is one of the most perplexing subjects in descriptive botany. We may classify the subject around three ideas: **solitary flowers**, **centrifugal** or **determinate clusters**, **centripetal** or **indeterminate clusters**.

**Solitary Flowers.**—In many cases flowers are borne singly; they are separated from other flowers by leaves. They are then said to be **solitary**. The solitary flower may



FIG. 212.—LATERAL FLOWER OF AN ABUTILON. A greenhouse plant.

be either at the end of the main shoot or axis (Fig. 211), when it is said to be **terminal**; or from the side of the shoot (Fig. 212), when it is said to be **lateral** or **axillary**.

**Centripetal Clusters.**—If the flower-bearing axils were rather close together, an open or leafy flower-cluster might result. If the plant continues to grow from the tip, the older flowers are left farther and farther behind. If the cluster were so short as to be flat or convex on top, the outermost flowers would be the

older. A flower-cluster in which the lower or outer flowers open first is said to be a **centripetal cluster**. It is sometimes said to be an **indeterminate** cluster, since it is the result of a type of growth which may go on more or less continuously from the apex.

The simplest form of a definite centripetal cluster is a **raceme**, which is an open elongated cluster in which the *flowers are borne singly on very short branches* and open from below (that is, from the older part of the shoot)

upwards (Fig. 213). The raceme may be *terminal* to the main branch; or it may be *lateral* to it, as in Fig. 214.

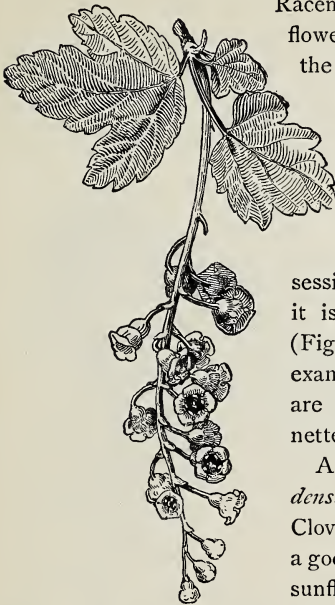


FIG. 213.—RACEME OF CURRANT.  
Terminal or lateral?

Racemes often bear the flowers on one side of the stem, thus forming a single row.

When a centripetal flower-cluster is long and dense and the flowers are sessile or nearly so, it is called a **spike** (Fig. 215). Common examples of spikes are plantain, mignonne, mullein.

A very *short and dense spike* is a **head**. Clover (Fig. 216) is a good example. The sunflower and related plants bear many small flowers in a

very dense and often flat head. Note that in the sunflower (Fig. 189) the outside or exterior flowers



FIG. 214.—LATERAL RACEMES (in fruit) OF BARBERRY.



FIG. 215.—  
SPIKE OF  
PLANTAIN.

open first. Another special form of spike is the **catkin**, which usually has scaly bracts, the whole cluster being deciduous after flowering or fruiting, and the flowers (in typical cases) having only stamens or pistils. Examples are the "pussies" of willows (Fig. 182) and flower-clusters of oak (Fig. 180), walnuts (Fig. 204), poplars.



FIG. 216. — HEAD OF CLOVER BLOSSOMS.



FIG. 217. — CORYMB OF CANDY-TUFT.

When a loose, elongated centripetal flower-cluster has some primary branches simple, and others irregularly branched, it is called a **panicle**. It is a branching raceme. Because of the earlier growth of the lower branches, the panicle is usually broadest at the base or conical in outline. True panicles are not very common.

When an indeterminate flower-cluster is short, so that

the *top is convex or flat*, it is a **corymb** (Fig. 217). The outermost flowers open first. Centripetal flower-clusters are sometimes said to be corymbose in mode.

When the branches of an indeterminate cluster *arise from a common point*, like the frame of an umbrella, the cluster is an **umbel** (Fig. 218). Typical umbels occur in carrot, parsnip, caraway, and other plants of the parsley family: the family is known as the Umbelliferæ, or umbel-bearing

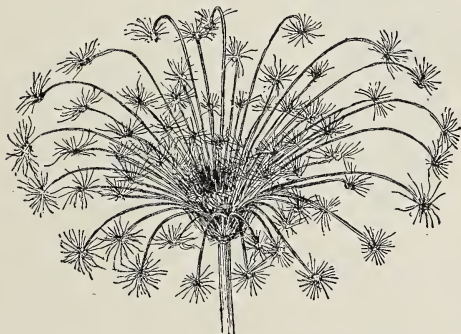


FIG. 218. — REMAINS OF A LAST YEAR'S UMBEL OF WILD CARROT.

family. In the carrot and many other Umbelliferæ, there are small or secondary umbels, called **umbellets**, at the end of each of the main branches. (In the centre of the wild carrot umbel one often finds a single, blackish, often aborted flower, comprising a 1-flowered umbellet.)

**Centrifugal or Determinate Clusters.**—When the terminal or central flower opens first, the cluster is said to be **centrifugal**. The growth of the shoot or cluster is **determinate**, since the length is definitely determined or stopped by the terminal flower. Fig. 219 shows a determinate or centrifugal mode of flower bearing.



FIG. 219.—DETERMINATE OR  
CYMOSE ARRANGEMENT.—  
Wild geranium.

Dense centrifugal clusters are usually flattish on top because of the cessation of growth in the main or central axis. These compact flower-clusters are known as **cymes**. Centrifugal clusters are sometimes said to be cymose in mode. Apples, pears (Fig. 220), and elders bear flowers in cymes. Some cyme-forms are like umbels in general appearance. A head-like cymose cluster is a **glomerule**; it blooms from the top downwards rather than from the base upwards.

**Mixed Clusters.**—Often the cluster is mixed, being determinate in one part and indeterminate in another part of the same cluster. The main cluster may be indeterminate, but the branches determinate. The cluster has the appearance of a panicle, and is usually so called, but it is really a **thyrs**e. Lilac is a familiar example of a thyrs. In some cases the main cluster is determinate and the branches are indeterminate, as in hydrangea and elder.

**Inflorescence.**—The *mode* or *method* of flower arrangement is known as the **inflorescence**. That is, the inflorescence is cymose, corymbose, paniculate, spicate, solitary, determinate, indeterminate. By custom, however, the word “inflorescence”



FIG. 220.—CYME OF PEAR.  
Often imperfect.



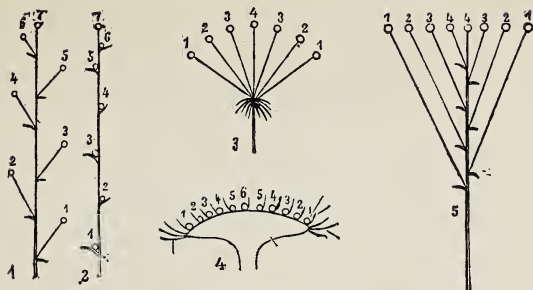


FIG. 221. — FORMS OF CENTRIPETAL FLOWER-CLUSTERS.

1, raceme; 2, spike; 3, umbel; 4, head or anthodium; 5, corymb.

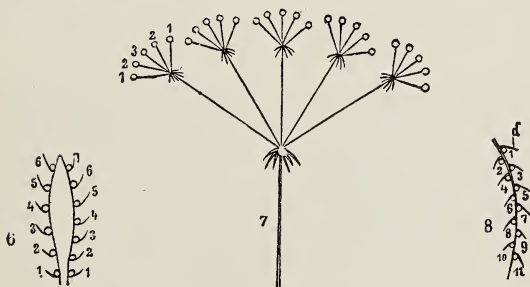


FIG. 222. — CENTRIPETAL INFLORESCENCE, *continued*.

6, spadix; 7, compound umbel; 8, catkin.

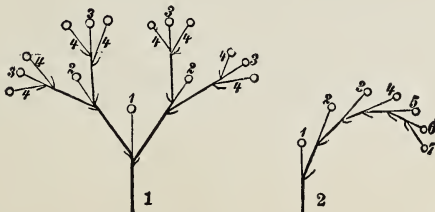


FIG. 223. — CENTRIFUGAL INFLORESCENCE.

1, cyme; 2, scirpioid raceme (or half cyme).

has come to be used in works on descriptive botany for the *flower-cluster itself*. Thus a cyme or a panicle may be called an inflorescence. It will be seen that even solitary flowers follow either indeterminate or determinate methods of branching.

**The flower-stem.**—The stem of a solitary flower is known as a **peduncle**; also the general stem of a *flower-cluster*. The stem of the individual flower in a cluster is a **pedicel**. In the so-called stemless plants the peduncle may arise directly from the ground, or crown of the plant, as in dandelion, hyacinth, garden daisy; this kind of peduncle is called a **scape**. A scape may bear one or many flowers. It has no foliage leaves, but it may have bracts.

**SUGGESTIONS.**—**166.** Name six columns in your notebook as follows: spike, raceme, corymb, umbel, cyme, solitary. Write each of the following in its appropriate column: larkspur, grape, rose, wistaria, onion, bridal wreath, banana, hydrangea, phlox, China berry, lily-of-the-valley, Spanish dagger (or yucca), sorghum, tuberose, hyacinth, mustard, goldenrod, peach, hollyhock, mullein, crêpe myrtle, locust, narcissus, snapdragon, peppergrass, shepherd's purse, coxcomb, wheat, hawthorn, geranium, carrot, elder, millet, dogwood, castor bean; substitute others for plants that do not grow in your region. **167.** In the study of flower-clusters, it is well to choose first those that are fairly typical of the various classes discussed in the preceding paragraphs. As soon as the main types are well fixed in the mind, random clusters should be examined, for the pupil must never receive the impression that all flower-clusters follow the definitions in books. Clusters of some of the commonest plants are very puzzling, but the pupil should at least be able to discover whether the inflorescence is determinate or indeterminate. Figures 221 to 223 illustrate the theoretical modes of inflorescence. The numerals indicate the order of opening.

## CHAPTER XXI

### FRUITS

THE ripened ovary, with its attachments, is known as the **fruit**. *It contains the seeds.* If the pistil is simple, or of one carpel, the fruit also will have one compartment. If the pistil is compound, or of more than one carpel, the fruit usually has an equal number of compartments. The compartments in pistil and fruit are known as **locules** (from Latin *locus*, meaning "a place").

The simplest kind of fruit is a *ripened 1-loculed ovary*. The

first stage in complexity is a ripened 2- or

*many-loculed ovary*. Very complex forms may arise by the *attachment of other parts to the ovary*. Sometimes the style persists and becomes a beak (mustard pods, dentaria, Fig. 224), or a tail as in clematis; or the calyx may be attached to the ovary; or the ovary may be embedded in the receptacle, and ovary and receptacle together constitute the fruit: or an involucre may become a part of the

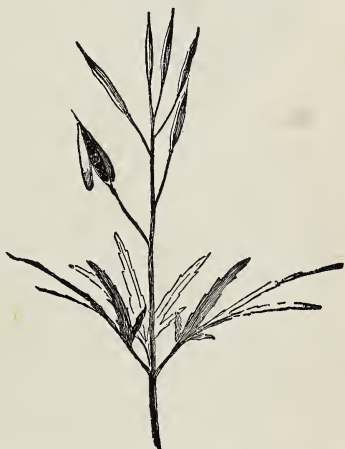


FIG. 224.—DENTARIA, OR TOOTH-WORT, in fruit.

fruit, as possibly in the walnut and the hickory (Fig. 225), and the cup of the acorn (Fig. 226). The chestnut and the beech bear a prickly involucre, but the nuts,



FIG. 225. — HICKORY-NUT.  
The nut is the fruit, contained in a husk.



FIG. 226. — LIVE-OAK ACORN.  
The fruit is the "seed" part; the involucre is the "cup."

or true fruits, are not grown fast to it, and the involucre can scarcely be called a part of the fruit. A ripened ovary is a **pericarp**. A pericarp to which other parts adhere has been called an accessory or reënforced fruit. (Page 169.)

Some fruits are **dehiscent**, or split open at maturity and liberate the seeds; others are **indehiscent**, or do not open.

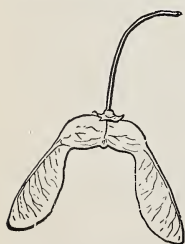


FIG. 227. — KEY OF  
SUGAR MAPLE.

A dehiscent pericarp is called a **pod**.

The parts into which such a pod breaks or splits are known as **valves**. In indehiscent fruits the seed is liberated by the decay of the envelope, or by the rupturing of the envelope by the germinating seed.



FIG. 228. — KEY  
OF COMMON  
AMERICAN ELM.

Indehiscent winged pericarps are known as **samaras** or **key fruits**. Maple (Fig. 227), elm (Fig. 228), and ash (Fig. 93) are examples.

**Pericarps.** — The simplest pericarp is a dry, one-seeded, indehiscent body. It is known as an **akene**. A head of akenes is shown in Fig. 229, and the structure is explained in Fig. 230. Akenes may be seen in buttercup, hepatica, anemone, smartweed, buckwheat.



FIG. 229.—  
AKENES OF  
BUTTERCUP.



FIG. 230.—AKENES  
OF BUTTERCUP,  
one in longitudinal  
section.

A 1-loculed pericarp which dehisces along the front edge (that is, the inner edge, next the centre of the flower is a **follicle**. The fruit of the larkspur (Fig. 231) is a follicle. There are usually five of these fruits (sometimes three or four) in each larkspur flower, each pistil ripening into a follicle. If these pistils were united, a single compound pistil would be formed. Columbine, peony, ninebark, milkweed, also have follicles.



FIG. 231.—  
FOLLICLE  
OF LARK-  
SPUR.

A 1-loculed pericarp that dehisces on both edges is a **legume**. Peas and beans are typical examples (Fig. 232); in fact, this character gives name to the pea family, — Leguminosæ.

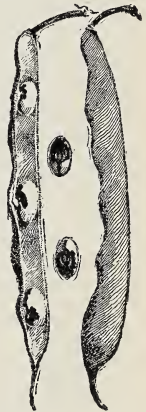


FIG. 232.—A  
BEAN POD.



FIG. 233.—CAPSULE OF  
CASTOR-OIL BEAN  
AFTER DEHISCENCE.

Often the valves of the legume twist forcibly and expel the seeds, throwing them some distance. The word "pod" is sometimes restricted to legumes, but it is better to use it generically for all dehiscent pericarps.

A compound pod — dehiscent pericarp of two or more carpels — is a **capsule** (Figs. 233, 234,



FIG. 234. — CAP-  
SULE OF MORN-  
ING GLORY.

236, 237). Some capsules are of one locule, but they may have been compound when young (in the ovary stage) and the partitions may have vanished. Sometimes one or more of the carpels are uniformly crowded out by the exclusive growth of other carpels (Fig. 235). The seeds or parts which are crowded out are said to be *aborted*.

There are several ways in which capsules dehisce or open. When they break *along the partitions* (or septa), the mode is known as **septicidal dehiscence** (Fig. 236); In septicidal dehiscence the fruit separates into parts representing the original carpels. These carpels may still be entire, and they then dehisce individually, usually along the inner edge as if they were follicles. When the compartments

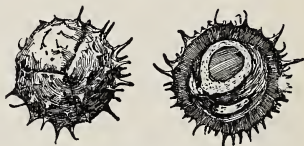


FIG. 235. — THREE-CARPELED FRUIT  
OF HORSE-CHESTNUT. Two locules  
are closing by abortion of the ovules.



FIG. 236. —  
ST. JOHN'S  
WORT. Sep-  
ticidal.



FIG. 237. —  
LOCULICI-  
DAL POD OF  
DAY-LILY.

*split in the middle, between the partitions*, the mode is **loculicidal dehiscence** (Fig. 237). In some cases the dehiscence is *at the top*, when it is said to be **apical** (although several modes of dehiscence are here included). When the *whole top comes off*, as in purslane and garden portulaca (Fig.

238), the pod is known as a **pyxis**. In some cases apical dehiscence is by means of a hole or clefts.

The peculiar capsule of the mustard family, or Cruci-



feræ, is known as a **silique** when it is distinctly longer than broad (Fig. 224), and a **silicle** when its breadth nearly



FIG. 238. — PYXIS OF PORTULACA OR ROSE-MOSS.



FIG. 239. — BERRIES OF GOOSEBERRY. Remains of calyx at c.

equals or exceeds its length. A cruciferous capsule is 2-carpeled, with a thin partition, each locule containing seeds in two rows. The two valves detach from below upwards. Cabbage, turnip, mustard, water-cress, radish,

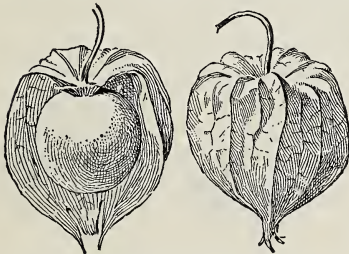


FIG. 240. — BERRY OF THE GROUND CHERRY OR HUSK TOMATO, contained in the inflated calyx.

The pericarp may be *fleshy and indehiscent*. A pulpy pericarp with several or many seeds is a **berry** (Figs. 239, 240, 241). To the horticulturist a berry is a small, soft, edible fruit, without

rape, shepherd's purse, sweet alyssum, wall-flower, honesty, are examples.

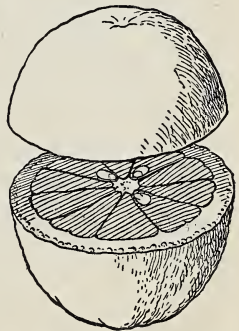


FIG. 241. — ORANGE; example of a berry.

particular reference to its structure. The botanical and horticultural conceptions of a berry are, therefore, unlike. In the botanical sense, gooseberries, currants, grapes, tomatoes, potato-balls, and even eggplant fruits and oranges (Fig. 241) are berries; strawberries, raspberries, blackberries are not.

A fleshy pericarp containing one relatively large seed or stone is a **drupe**. Examples are plum (Fig. 242), peach, cherry, apricot, olive. The walls of the pit in the plum, peach, and cherry are formed from the inner coats of the ovary, and the flesh from the outer coats. Drupes are also known as *stone-fruits*.



FIG. 242. — PLUM; example of a drupe.

Fruits that are formed by the subsequent union of separate pistils are **aggregate fruits**. The carpels in aggregate fruits are usually more or less fleshy. In the raspberry and the blackberry flower, the pistils are essentially distinct, but as the pistils ripen they cohere and form one body (Figs. 243, 244).

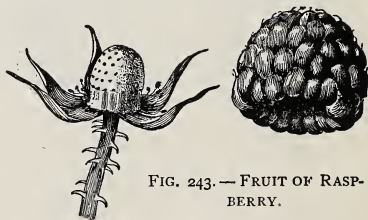


FIG. 243. — FRUIT OF RASPBERRY.



FIG. 244. — AGGREGATE FRUIT OF MULBERRY; and a separate fruit.

Each of the carpels or pistils in the raspberry and the blackberry is a little drupe or **drupelet**. In the raspberry the entire fruit separates from the torus, leaving the torus on the plant. In the blackberry and

the dewberry the fruit adheres to the torus, and the two are removed together when the fruit is picked.

**Accessory Fruits.**—When the pericarp and some other part grow together, the fruit is said to be **accessory** or **reënforced**. An example is the strawberry (Fig. 245). The edible part is a greatly *enlarged torus*, and the pericarps are akenes embedded in it. These akenes are commonly called seeds.

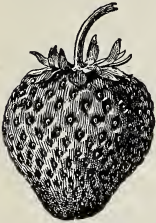


FIG. 245. — STRAWBERRY; fleshy torus in which akenes are embedded.

Various kinds of reënforced fruits have received special names. One of these is the **hip**, characteristic of roses. In this case, the torus is deep and hollow, like an urn, and the separate akenes are borne inside it. The mouth of the receptacle may close, and the walls sometimes become fleshy; the fruit may then be mistaken for a berry. The fruit of the pear, apple, and quince is known as a

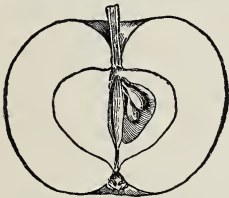


FIG. 246. — SECTION OF AN APPLE.

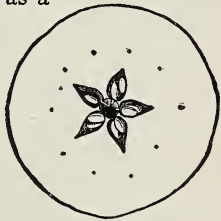


FIG. 247. — CROSS-SECTION OF AN APPLE.

**pome.** In this case the five united carpels are completely buried in the hollow torus, and the torus makes most of the edible part of the ripe fruit, while the pistils are represented by the core (Fig. 246). Observe the sepals on the top of the torus (apex of the fruit) in Fig. 246. Note the outlines of the embedded pericarp in Fig. 247.

**Gymnospermous Fruits.**—In pine, spruces, and their kin, there is no fruit in the sense in which the word is used in the preceding pages, because *there is no ovary*. The ovules are naked or uncovered, in the axils of the scales of the young cone, and they have neither style nor stigma. The pollen falls directly on the mouth of the ovule. The ovule ripens into a seed, which is usually winged. Because the ovule is not borne in a sac or ovary, these plants are called **gymnosperms** (Greek for “naked seeds”). All the true cone-bearing plants are of this class; also certain other plants, as red cedar, juniper, yew. The plants are monœcious or sometimes diœcious. The staminate flowers are mere naked stamens borne beneath scales, in small yellow catkins which soon fall. The pistillate flowers are naked ovules beneath scales on cones that persist (Fig. 29). Gymnospermous seeds may have several cotyledons.

**SUGGESTIONS.—168.** Study the following fruits, or any five fruits chosen by the teacher, and answer the questions for each: Apple, peach, bean, tomato, pumpkin. What is its form? Locate the scar left by the stem. By what kind of stem was it attached? Are there any remains of the blossom at the blossom end? Describe texture and colour of surface. Divide the fruit into the seed vessel and the surrounding part. Has the fruit any pulp or flesh? Is it within or without the seed vessel? Is the seed vessel simple or sub-divided? What is the number of seeds? Are the seeds free, attached to the wall of the vessel, or to a support in the centre? Are they arranged in any order? What kind of wall has the seed vessel? What is the difference between a peach stone and a peach seed? **169.** The nut fruits are always available for study. Note the points suggested above. Determine what the meat or edible part represents, whether cotyledons or not. Figure 248 is suggestive. **170.** Mention all the fleshy fruits you know, tell where they come from, and refer them to their proper groups. **171.** What kinds of fruit can you buy in the market, and to what groups or classes do they belong? Of which fruits are the seeds only, and not the pericarps, eaten? **172.** An ear of corn is always available for study. What is it—a fruit or a collection of fruits? How are the grains arranged on the cob? How many rows do you count on each of several ears? Are all the rows on an ear

equally close together? Do you find an ear with an odd number of rows? How do the parts of the husk overlap? Does the husk serve as protection from rain? Can birds pick out the grains? How do insect enemies enter the ear? How and when do weevils lay eggs on corn? **173. Study a grain of corn.** Is it a seed? Describe the shape of a grain. Colour. Size. Does its surface show any projections or depressions? Is the seed-coat thin or thick? Transparent or opaque? Locate the hilum. Where is the silk scar? What is the silk? Sketch the grain from the two points of view that show it best. Where is the embryo? Does the grain have endosperm? What is dent corn? Flint corn? How many kinds of corn do you know? For what are they used?

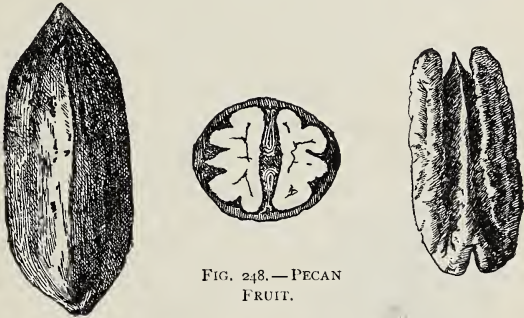


FIG. 248.—PECAN  
FRUIT.

**NOTE TO TEACHER.**—There are few more interesting subjects to beginning pupils than fruits,—the pods of many kinds, forms, and colours, the berries, and nuts. This interest may well be utilized to make the teaching alive. All common edible fruits of orchard and vegetable garden should be brought into this discussion. Of dry fruits, as pods, burs, nuts, collections may be made for the school museum. Fully mature fruits are best for study, particularly if it is desired to see dehiscence. For comparison, pistils and partially grown fruits should be had at the same time. If the fruits are not ripe enough to dehisce, they may be placed in the sun to dry. In the school it is well to have a collection of fruits for study. The specimens may be kept in glass jars. *Always note exterior of fruit and its parts; interior of fruit with arrangement and attachment of contents.*

## CHAPTER XXII

### DISPERSAL OF SEEDS

It is to the plant's advantage to have its seeds distributed as widely as possible. *It has a better chance of surviving in the struggle for existence.* It gets away from competition. Many seeds and fruits are of such character as to increase their chances of wide dispersal. The commonest means of dissemination may be classed under four heads: *explosive fruits; transportation by wind; transportation by birds; burs.*



FIG. 249. — EXPLOSION OF THE BALSAM POD.



FIG. 250. — EXPLOSIVE FRUITS OF OXALIS.

An exploding pod is shown at *c*. The dehiscence is shown at *b*. The structure of the pod is seen at *a*.

**Explosive Fruits.** — *Some pods open with explosive force and discharge the seeds.* Even beans and everlasting peas do this. More marked examples are the locust, witch hazel, garden balsam (Fig. 249), wild jewel-weed or impatiens (touch-me-not), violet, crane's-bill or wild geranium, bull nettle, morning glory, and the oxalis (Fig. 250). The



oxalis is common in several species in the wild and in cultivation. One of them is known as wood sorrel. Figure 250 shows the common yellow oxalis. The pod opens loculicidally. The elastic tissue suddenly contracts when dehiscence takes place, and the seeds are thrown violently. The squirting cucumber is easily grown in a garden (procure seeds of seedsmen), and the fruits discharge the seeds with great force, throwing them many feet.

**Wind Travelers.** — Wind-transported seeds are of two general kinds: those that are *provided with wings*, as the flat seeds of catalpa (Fig. 251) and cone-bearing trees and the samaras of ash, elm, tulip-tree, ailanthus, and maple; and those which have *feathery buoys* or *parachutes* to enable them to float in the air. Of the latter kind are the fruits of many composites, in which the pappus is copious and soft. Dandelion and thistle are examples. The silk of the milkweed and probably the hairs on the cotton seed have a similar office, and also the wool of the cat-tail. Recall the cottony seeds of the willow and the poplar.



FIG. 251. — WINGED SEEDS OF CATALPA.

**Dispersal by Birds.** — *Seeds of berries and of other small fleshy fruits are carried far and wide by birds.* The pulp is digested, but the seeds are not injured. Note how the cherries, raspberries, blackberries, June-berries, and others spring up in the fence rows, where the birds rest. Some berries and drupes persist far into winter, when they supply food to cedar birds, robins, and the winter birds. Red cedar is distributed by birds. Many of these pulpy

fruits are agreeable as human food, and some of them have been greatly enlarged or "improved" by the arts of the cultivator. The seeds are usually indigestible.

**Burs.**—Many seeds and fruits bear spines, hooks, and hairs, which *adhere to the coats of animals and to clothing*. The burdock has an involucre with hooked scales, containing the fruits inside. The clotbur is also an involucre. Both are composite plants, allied to thistles, but the

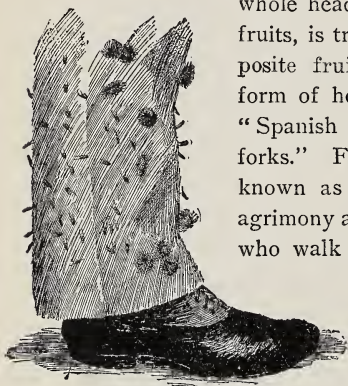


FIG. 252.—STEALING A RIDE.

whole head, rather than the separate fruits, is transported. In some composite fruits the pappus takes the form of hooks and spines, as in the "Spanish bayonets" and "pitchforks." Fruits of various kinds are known as "stick tights," as of the agrimony and hound's-tongue. Those who walk in the woods in late summer and fall are aware

that plants have means of disseminating themselves (Fig. 252). If it is impossible to identify the burs which one

finds on clothing, the seeds may be planted and specimens of the plant may then be grown.

**SUGGESTIONS.**—**174.** What advantage is it to the plant to have its seeds widely dispersed? **175.** What are the leading ways in which fruits and seeds are dispersed? **176.** Name some explosive fruits. **177.** Describe wind travelers. **178.** What seeds are carried by birds? **179.** Describe some bur with which you are familiar. **180.** Are adhesive fruits usually dehiscent or indehiscent? **181.** Do samaras grow on low or tall plants, as a rule? **182.** Are the cotton fibres on the seed or on the fruit? **183.** Name the ways in which the common weeds of your region are disseminated. **184.** This lesson will suggest other ways in which

seeds are transported. Nuts are buried by squirrels for food ; but if they are not eaten, they may grow. The seeds of many plants are blown on the snow. The old stalks of weeds, standing through the winter, may serve to disseminate the plant. Seeds are carried by water down the streams and along shores. About woollen mills strange plants often spring up from seed brought in the fleeces. Sometimes the entire plant is rolled for miles before the winds. Such plants are "tumbleweeds." Examples are Russian thistle, hair grass or tumblegrass (*Panicum capillare*), cyclone plant (*Cycloloma platyphyllum*), and white amaranth (*Amarantus albus*). About seaports strange plants are often found, having been introduced in the earth that is used in ships for ballast. These plants are usually known as "ballast plants." Most of them do not persist long. 185. Plants are able to spread themselves by means of the great numbers of seeds that they produce. How many seeds may a given elm tree or apple tree or raspberry bush produce?



FIG. 253. — THE FRUITS OF THE CAT-TAIL ARE LOOSENED BY WIND AND WEATHER.

## CHAPTER XXIII

### PHENOGAMS AND CRYPTOGAMS

THE plants thus far studied produce flowers; and the flowers produce seeds by means of which the plant is propagated. There are other plants, however, that produce no seeds, and these plants (including bacteria) are probably more numerous than the seed-bearing plants. These plants propagate by means of **spores**, *which are generative cells, usually simple, containing no embryo*. These spores are very small, and sometimes are not visible to the naked eye.

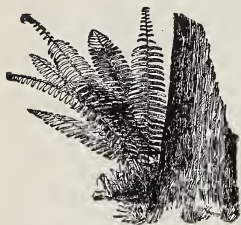


FIG. 254. — CHRISTMAS FERN.  
— *Dryopteris acrostichoides*;  
known also as *Aspidium*.

Prominent among the spore-propagated plants are *ferns*. The common *Christmas fern* (so called because it remains green during winter) is shown in Fig. 254. The plant has no trunk. The leaves spring directly from the ground. The leaves of ferns are called **fronds**. They vary in shape, as other leaves do. Some of the fronds in Fig. 254 are seen to be narrower at the top. If these are examined more closely (Fig. 255),



FIG. 255. — FRUITING FROND  
OF CHRISTMAS FERN.

Sori at *a*. One sorus with its indusium at *b*.

it will be seen that the leaflets are contracted and are densely covered beneath with brown bodies. These bodies are collections of **sporangia** or **spore-cases**.



FIG. 256. — COMMON POLYPODE FERN.  
*Polypodium vulgare*.



FIG. 257. — SORI AND SPORANGIUM OF POLYPODE.  
A chain of cells lies along the top of the sporangium, which springs back elastically on drying, thus disseminating the spores.

The sporangia are collected into little groups, known as **sori** (singular, **sorus**) or **fruit-dots**. Each sorus is covered with a thin scale or shield, known as an **indusium**. This indusium separates from the frond at its edges, and the sporangia are exposed. Not all ferns have indusia. The polypode (Figs. 256, 257) does not; the sori are naked. In the brake (Fig. 258)



FIG. 258. — THE BRAKE FRUITS UNDERNEATH THE REVOLUTE EDGES OF THE LEAF.



FIG. 259. — FRUITING PINNAE OF MAIDENHAIR FERN.

and maidenhair (Fig. 259) the edge of the frond turns over and forms an indusium. The nephrolepis or sword fern of greenhouses is allied to the polypode. The sori are in a single row on either side the midrib (Fig. 260). The indusium is circular or kidney-shaped and open at one edge

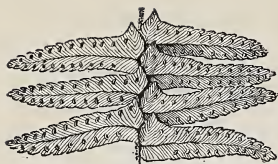


FIG. 260. — PART OF FROND OF SWORD FERN. To the pupil: Is this illustration right side up?

or finally all around. The Boston fern, Washington fern, Pierson fern, and others, are horticultural forms of the common sword fern. In some ferns (Fig. 261) an entire frond becomes contracted to cover the sporangia.

The sporangium or spore-case of a fern is a more or less globular body and usually with a stalk (Fig. 257). *It contains the spores. When ripe it bursts and the spores are set free.*

In a moist, warm place *the spores germinate*. They produce a small, flat, thin, green, more or less heart-shaped membrane (Fig. 262). This is the **prothallus**. Sometimes the prothallus is an inch or more across, but oftener it is less than a ten cent piece in size. Although easily seen, it is commonly unknown except to botanists. Prothalli may often be found in greenhouses where ferns are grown.



FIG. 261. — FERTILE AND STERILE FRONDS OF THE SENSITIVE FERN.



FIG. 262. — PROTHALLUS OF A FERN. Enlarged.

Archegonia at *a*; antheridia at *b*.

Look on the moist stone or brick walls, or on the firm soil of undisturbed pots and beds; or spores may be sown in a damp, warm place.

On the under side of the prothallus two kinds of organs are borne. These are the **archegonium** (containing egg-cells) and the **antheridium** (con-



taining sperm-cells). These organs are minute specialized parts of the prothallus. Their positions on a particular prothallus are shown at *a* and *b* in Fig. 262, but in some ferns they are on separate prothalli (plant dioecious). *The sperm-cells escape from the antheridium and in the water that collects on the prothallus are carried to the archegonium, where fertilization of the egg takes place.* From the fertilized egg-cell a plant grows, becoming a "fern." In most cases the prothallus soon dies. The prothallus is the **gametophyte** (from Greek, signifying the fertilized plant).

The fern plant, arising from the fertilized egg in the archegonium, becomes a perennial plant, each year producing spores from its fronds (called the **sporophyte**); but these spores—which are merely detached special kinds of cells—produce the prothallic phase of the fern plant, from which new individuals arise. *A fern is fertilized but once in its lifetime.* The "fern" bears the spore, the spore gives rise to the prothallus, and the egg-cell of the prothallus (when fertilized) gives rise to the fern.

A similar alternation of generations runs all through the vegetable kingdom, although there are some groups of plants in which it is very obscure or apparently wanting. It is very marked in ferns and mosses. In algæ (including the seaweeds) the gametophyte is the "plant," as the non-botanist knows it, and the sporophyte is inconspicuous. *There is a general tendency, in the evolution of the vegetable kingdom, for the gametophyte to lose its relative importance and for the sporophyte to become larger and more highly developed.* In the seed-bearing plants the sporophyte generation is the only one seen by the non-botanist. The gametophyte stage is of short duration and the parts are small; it is confined to the time of fertilization.

The sporophyte of seed plants, or the "plant" as we know it, produces two kinds of spores — one kind becoming **pollen-grains** and the other kind **embryo-sacs**. The pollen-spores are borne in sporangia, which are united into what are called **anthers**. The embryo-sac, which contains the egg-cell, is borne in a sporangium known as an **ovule**. *A gametophytic stage is present in both pollen and embryo sac: fertilization takes place, and a sporophyte arises. Soon this sporophyte becomes dormant, and is then known as an embryo.* The embryo is packed away within tight-fitting coats, and the entire body is the **seed**. When the conditions are right the seed grows, and the sporophyte grows into herb, bush, or tree. The utility of the alternation of generations is not understood.

The spores of ferns are borne on leaves; the spores of seed-bearing plants are also borne amongst a mass of specially developed conspicuous leaves known as **flowers**; therefore these plants have been known as the **flowering plants**. Some of the leaves are developed as envelopes (calyx, corolla), and others as spore-bearing parts, or **sporophylls** (stamens, pistils). But the spores of the lower plants, as of ferns and mosses, may also be borne in specially developed foliage, so that the line of demarcation between flowering plants and flowerless plants is not so definite as was once supposed. The one definite distinction between these two classes of plants is the fact that *one class produces seeds and the other does not*. The seed-plants are now often called **spermaphytes**, but there is no single coördinate term to set off those which do not bear seeds. It is quite as well, for popular purposes, to use the terms **phenogams** for the seed-bearing plants and **cryptogams** for the others. These terms have been objected to in recent years because their etymology does not express literal facts

(*phenogam* signifying "showy flowers," and *cryptogam* "hidden flowers"), but the terms represent distinct ideas in classification. The cryptogams include three great series of plants—the **Thallophytes** or algæ, lichens, and fungi; the **Bryophytes** or mosslike plants; the **Pteridophytes** or fernlike plants.

**SUGGESTIONS. — 186.** *The parts of a fern leaf.* The primary complete divisions of a frond are called pinnae, no matter whether the frond is pinnate or not. In ferns the word "pinna" is used in essentially the same way that leaflet is in the once-compound leaves of other plants. The secondary leaflets are called pinnules, and in thrice, or more, compound fronds, the last complete parts or leaflets are ultimate pinnules. The diagram (Fig. 263) will aid in making the subject clear. If the frond were not divided to the midrib, it would be simple, but this diagram represents a compound frond. The general outline of the frond, as bounded by the dotted line, is ovate. The stipe is very short. The midrib of a compound frond is known as the rachis. In a decompound frond, this main rachis is called the primary rachis. Segments (not divided to the rachis) are seen at the tip, and down to *h* on one side and to *m* on the other. Pinnæ are shown at *i*, *k*, *l*, *o*, *n*. The pinna *o* is entire; *n* is crenate-dentate; *i* is sinuate or wavy, with an auricle at the base; *k* and *l* are compound. The pinna *k* has twelve entire pinnules. (Is there ever an even number of pinnules on any pinna?) Pinna *l* has nine compound pinnules, each bearing several entire ultimate pinnules. *The spores. — 187.* Lay a mature fruiting frond of any fern on white paper, top side up, and allow it to remain in a dry, warm place. The spores will discharge on the paper.

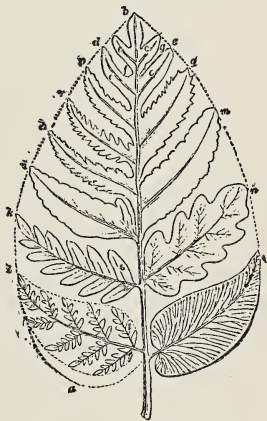


FIG. 263.—DIAGRAM TO EXPLAIN THE TERMINOLOGY OF THE FROND.

**188.** Lay the full-grown (but not dry) cap of a mushroom or toadstool bottom down on a sheet of clean paper, under a ventilated box in a warm, dry place. A day later raise the cap.

## CHAPTER XXIV

### STUDIES IN CRYPTOGAMS

THE pupil who has acquired skill in the use of the compound microscope may desire to make more extended excursions into the cryptogamous orders. The following plants have been chosen as examples in various groups. Ferns are sufficiently discussed in the preceding chapter.

#### BACTERIA

If an infusion of ordinary hay is made in water and allowed to stand, it becomes turbid or cloudy after a few days, and a drop under the microscope will show the presence of minute oblong cells swimming in the water, perhaps by means of numerous hair-like appendages, that project through the cell wall from the protoplasm within. At the surface of the dish containing the infusion the cells are non-motile and are united in long chains. Each of these cells or organisms is a *bacterium* (plural, *bacteria*). (Fig. 135.)

Bacteria are very minute organisms,—the smallest known—consisting either of separate oblong or spherical cells, or of chains, plates, or groups of such cells, depending on the kind. They possess a membrane-like wall which, unlike the cell walls of higher plants, contains nitrogen. The presence of a nucleus has not been definitely demonstrated. Multiplication is by the fission of the vegetative cells; but under certain conditions of drought, cold, or exhaustion of the nutrient medium, the protoplasm of the ordinary cells may become invested with a thick wall, thus forming an *endospore* which is very resistant to extremes of environment. No sexual reproduction is known.

Bacteria are very widely distributed as parasites and saprophytes in almost all conceivable places. *Decay* is largely caused by bacteria, accompanied in animal tissue by the liberation of foul-smelling gases. Certain species grow in the reservoirs and pipes of water supplies, rendering the water brackish and often undrinkable. Some kinds of *fermentation* (the breaking down or decomposing of organic compounds, usually accompanied by the

formation of gas) are due to these organisms. Other bacteria oxidize alcohol to *acetic acid*, and produce *lactic acid* in milk and *butyric acid* in butter. Bacteria live in the mouth, the stomach, the intestines, and on the surface of the skins of animals. Some secrete gelatinous sheaths around themselves; others secrete sulphur or iron, giving the substratum a vivid colour.

Were it not for bacteria, man could not live on the earth, for not only are they agents in the process of decay, but they are concerned in certain healthful processes of plants and animals. We have learned in Chapter VIII how bacteria are related to nitrogen-gathering.

Bacteria are of economic importance not alone because of their effect on materials used by man, but also because of the *disease-producing power* of certain species. *Pus* is caused by a spherical form, *tetanus* or *lock-jaw* by a rod-shaped form, *diphtheria* by short oblong chains, *tuberculosis* or "*consumption*" by more slender oblong chains, and *typhoid fever*, *cholera*, and other diseases by other forms. Many *diseases of animals and plants* are caused by bacteria. Disease-producing bacteria are said to be *pathogenic*.

The ability to grow in other nutrient substances than the natural one has greatly facilitated the study of these minute forms of life. By the use of suitable culture media and proper precautions, *pure cultures* of a particular disease-producing bacterium may be obtained with which further experiments may be conducted.

Milk provides an excellent collecting place for bacteria coming from the air, from the coat of the cow and from the milker. Disease germs are sometimes carried in milk. If a drop of milk is spread on a culture medium (as agar), and provided with proper temperature, the bacteria will multiply, each one forming a colony visible to the naked eye. In this way, the number of bacteria originally contained in the milk may be counted.

Bacteria are disseminated in water, as the germ of typhoid fever and cholera; in milk and other fluids; in the air; and on the bodies of flies, feet of birds, and otherwise.

Bacteria are thought by many to have descended from algæ by the loss of chlorophyll and decrease in size due to the more specialized acquired saprophytic and parasitic habit.

## ALGÆ

The algæ comprise most of the green floating "scum" which covers the surfaces of ponds and other quiet waters. The masses of plants are often called "frog spittle." Others are attached to stones, pieces of wood, and other objects submerged in streams

and lakes, and many are found on moist ground and on dripping rocks. Aside from these, all the plants commonly known as seaweeds belong to this category; these latter are inhabitants of salt water.

The simplest forms of algæ consist of a single spherical cell, which multiplies by repeated division or fission. Many of the forms found in fresh water are filamentous, *i.e.* the plant body consists of long threads, either simple or branched. Such a plant body is termed a *thallus*. This term applies to the vegetative body of all plants that are *not differentiated into stem and leaves*. Such plants are known as *thallophytes* (p. 181). All algæ contain chlorophyll, and are able to assimilate carbon dioxide from the air. This distinguishes them from the fungi.

*Nostoc*. — On wet rocks and damp soil dark, semitransparent irregular or spherical gelatinous masses about the size of a pea are often found. These consist of a colony of contorted filamentous algæ embedded in the jelly-like mass. The chain of cells in the filament is necklace-like. Each cell is homogeneous, without apparent nucleus, and blue-green in colour, except one cell which is larger and clearer than the rest. The plant therefore belongs to the group of *blue-green algæ*. The jelly probably serves to maintain a more even moisture and to provide mechanical protection. Multiplication is wholly by the breaking up of the threads. Occasionally certain cells of the filament thicken to become *resting-spores*, but no other spore formation occurs.

*Oscillatoria*. — The blue-green coatings found on damp soil and in water frequently show under the microscope the presence of filamentous algæ composed of many short



FIG. 264. — FILAMENT OF OSCILLATORIA, showing one dead cell where the strand will break.

homogeneous cells (Fig. 264). If watched closely, some filaments will be seen to wave back and forth slowly, showing a peculiar power of movement characteristic of this plant. Multiplication is by the breaking up of the threads. There is no true spore formation.

*Spirogyra*. — One of the most common forms of the green algæ is spirogyra (Fig. 265). This



FIG. 265. — STRAND OF SPIROGYRA, showing the chlorophyll bands. There is a nucleus at *a*. How many cells, or parts of cells, are shown in this figure?



plant often forms the greater part of the floating green mass (or "frog spittle") on ponds. The threadlike character of the thallus can be seen with the naked eye or with a hand lens, but to study it carefully a microscope magnifying two hundred diameters or more must be used. The thread is divided into long cells by cross walls which, according to the species, are either straight or curiously folded (Fig. 266). The chlorophyll is arranged in *beautiful spiral bands* near the wall of each cell. From the character of these bands the plant takes its name. Each cell is provided with a *nucleus* and other *protoplasm*. The nucleus is suspended near the centre of the cell (*a*, Fig. 265) by delicate strands of protoplasm radiating toward the wall and terminating at certain points in the chlorophyll band. The remainder of the protoplasm forms a thin layer lining the wall. The interior of the cell is filled with cell-sap. The protoplasm and nucleus cannot be easily seen, but if the plant is stained with a dilute alcoholic solution of eosine they become clear.

Spirogyra is propagated vegetatively by the breaking off of parts of the threads, which continue to grow as new plants. Resting-spores, which may remain dormant for a time, are formed by a process known as *conjugation*. Two threads lying side by side send out short projections, usually from all the cells of a long series (Fig. 266). The projections or processes from opposite cells grow toward each other, meet, and fuse, forming a connecting tube between the cells. The protoplasm, nucleus, and chlorophyll band of one cell now pass through this tube, and unite with the contents of the other cell. The entire mass then becomes surrounded by a thick cellulose wall, thus completing the *resting-spore*, or *zygospore* (*z*, Fig. 266).



FIG. 266. — CONJUGATION OF SPIROGYRA. Ripe zygospores on the left; *a*, connecting tubes.



FIG. 267. — STRAND, OR FILAMENT OF ZYGNEMA, freed from its gelatinous covering.

*Zygnema* is an alga closely related to *spirogyra* and found in similar places. Its life history is practically the same, but it differs from *spirogyra* in having *two star-shaped chlorophyll bodies* (Fig. 267) in each cell, instead of a chlorophyll-bearing spiral band.

*Vaucheria* is another alga common in shallow water and on damp soil. The thallus is much branched, but the threads are not divided by cross walls as in *spirogyra*. The plants are attached by means of colourless root-like organs which are much like the root hairs of the higher plants: these are *rhizoids*. The chlorophyll is in the form of *grains scattered through the thread*.

*Vaucheria* has a special mode of asexual reproduction by means of swimming spores or *swarm-spores*. These are formed singly in a short enlarged lateral branch known as the *sporangium*. When the sporangium bursts, the entire contents escape, forming a single large swarm-spore, which swims about by means of numerous lashes or cilia on its surface. The swarm spores are so large that they can be seen with the naked eye. After swimming about for some time they come to rest and germinate, producing a new plant.

The formation of resting-spores of *vaucheria* is accomplished by means of special organs, *oögonia* (*o*, Fig. 268) and *antheridia*



FIG. 268. — THREAD OF VAUCHERIA WITH OÖGONIA AND ANTHERIDIA.

(*a*, Fig. 268). These are both specially developed branches from the thallus. The antheridia are nearly cylindrical, and curved toward the oögonia. The upper part of an antheridium is cut off by a cross wall, and within it

numerous ciliated *sperm-cells* are formed. These escape by the ruptured apex of the antheridium. The oögonia are more enlarged than the antheridia, and have a beak-like projection turned a little to one side of the apex. They are separated from the thallus thread by a cross wall, and contain a single large green cell, the *egg-cell*. The apex of the oögonium is dissolved, and through the opening the sperm-cells enter. Fertilization is thus accomplished. After fertilization the egg-cell becomes invested with a thick wall and is thus converted into a resting-spore, the *öospore*.

*Fucus*. — These are rather large specialized algæ belonging to the group known as brown seaweeds and found attached by a disk to the rocks of the seashore just below high tide (Fig. 269). They are firm and strong to resist wave action and are so attached as to avoid being washed ashore. They are very abundant algæ. In shape the plants are long, branched, and multicellular, with either flat or terete branches. They are olive-brown. Propagation is by the breaking off of the branches. No zoöspores are produced, as in many other seaweeds; and reproduction is wholly sexual.

The *antheridia*, bearing *sperm-cells*, and the *oögonia*, each bearing eight *egg-cells*, are sunken in pits or *conceptacles*. These pits are aggregated in the swollen lighter coloured tips of some of the branches (*s, s*, Fig. 269). The egg-cells and sperm-cells escape from the pits and fertilization takes place in the water. The matured eggs, or spores, reproduce the fucus plant directly.



FIG. 269. — FUCUS. Fruiting branches at *s, s*. On the stem are two air-bladders.



FIG. 270. — NITELLA.

*Nitella*. — This is a large branched and specialized fresh-water alga found in tufts attached to the bottom in shallow ponds (Fig. 270). Between the whorls of branches are long *internodes consisting of a single cylindrical cell*, which is one of the largest cells known in vegetable tissue. Under the microscope the walls of this cell are found to be lined with a layer of small stationary chloroplastids, within which layer the protoplasm, in favourable circumstances, will be found in motion, moving up one side and down the other (in rotation). Note the clear streak up the side of the cell and its relation to the moving current.

## FUNGI

Some forms of fungi are familiar to every one. Mushrooms and toadstools, with their varied forms and colours, are common in fields, woods, and pastures. In every household the common moulds are familiar intruders, appearing on old bread, vegetables, and even within tightly sealed fruit jars, where they form a felt-like layer dusted over with blue, yellow, or black powder. The strange occurrence of these plants long mystified people, who

thought they were productions of the dead matter upon which they grew, but now we know that a mould, as any other plant, cannot originate spontaneously; it must start from something which is analogous to a seed. The "seed" in this case is a *spore*. A spore may be produced by a *vegetative process* (growing out from the ordinary plant tissues), or it may be the result of a *fertilization process*.

*Favourable conditions for the growth of fungi.*—Place a piece of bread under a moist bell jar and another in an uncovered place near by. Sow mould on each. Note the result from day to day. Moisten a third piece of bread with weak copper sulphate

(blue vitriol) or mercuric chloride solution, sow mould, cover with bell jar, note results, and explain. Expose pieces of different kinds of food in a damp atmosphere and observe the variety of organisms appearing. Fungi are saprophytes or parasites, and must be provided with organic matter on which to grow. They are usually most abundant in moist places and wet seasons.

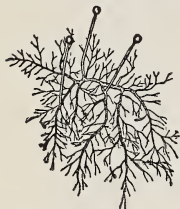


FIG. 271. — MUCOR MUCEDO, showing habit.

*Mould.*—One of these moulds (*Mucor mucedo*), which is very common on all decaying fruits and vegetables, is shown in Fig. 271, somewhat magnified. When fruiting, this mould appears as a dense mass of long white hairs, often over an inch high, standing erect from the fruit or the vegetable on which it is growing.

The life of this mucor begins with a minute rounded spore (*a*, Fig. 272), which lodges on the decaying material. When the spore germinates, it sends out a delicate thread that grows rapidly in length and forms very many branches that soon permeate every part of the substance on which the plant grows. (*b*, Fig. 272). One of these threads is termed a *hypha*. All the threads together form the *mycelium* of the fungus. The mycelium disorganizes the material in which it grows, and thus the mucor plant (Fig. 271) is nourished. It corresponds physiologically to the roots and the stems of other plants.



FIG. 272. — SPORES OF MUCOR, some germinating.

When the mycelium is about two days old, it begins to form the long fruiting stalks which we first noticed. To study them, use a compound microscope magnifying about two hundred diameters. One of the stalks, magnified, is shown in *a*, Fig. 274. It consists of a rounded head, the *sporangium*, *sp*, supported on a long,

delicate stalk, the *sporangiophore*. The stalk is separated from the sporangium by a wall which is formed at the base of the sporangium. This wall, however, does not extend straight across the thread, but it arches up into the sporangium like an inverted pear. It is known as the *columella*, *c*. When the sporangium is placed in water, the wall immediately dissolves and allows hundreds of spores, which were formed in the cavity within the sporangium, to escape, *b*. All that is left of the fruit is the stalk, with the pear-shaped columella at its summit, *c*. The spores that have been set free by the breaking of the sporangium wall are now scattered by the wind and other agents. Those that lodge in favourable places begin to grow immediately and reproduce the fungus. The others soon perish.

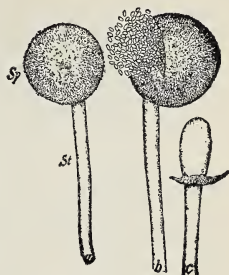


FIG. 274. — MUCOR.

*a*, sporangium; *b*, sporangium bursting; *c*, columella.

The mucor may continue to reproduce itself in this way indefinitely, but these spores are very delicate and

usually die if they do not fall on favourable ground, so that the fungus is provided with another means of carrying itself over unfavourable seasons, as winter. This is accomplished by means of curious *thick-walled resting-spores* or *zygospores*. The zygospores are formed on the mycelium buried within the substance on which the plant grows. They originate in the following way: Two threads that lie near together send out short branches, which grow toward each other and finally meet (Fig. 273). The walls at the ends, *a*, then disappear, allowing the contents to flow together. At the same time, however, two other walls are formed at points farther back, *b, b*, separating the short section, *c*, from the remainder of the thread. This section now increases in size and becomes covered with a thick, dark brown wall ornamented with thickened tubercles. The zygospore is now mature and, after a period of rest, it germinates, either producing a sporangium directly or growing out as mycelium.



FIG. 273. — MUCOR, showing formation of zygospore on the right; germinating zygospore on the left.

The zygospores of the mucors form one of the most interesting and instructive objects among the lower plants. They are, however, very difficult to obtain. One of the mucors (*Sporodina*



*grandis*) may be frequently found in summer growing on toadstools. This plant usually produces zygospores that are formed on the aërial mycelium. The zygospores are large enough to be recognized with a hand lens. The material may be dried and kept for winter study, or the zygospores may be prepared for permanent microscopic mounts in the ordinary way.

*Yeast.*—This is a very much reduced and simple fungus, consisting normally of isolated spherical or elliptical cells (Fig. 275)

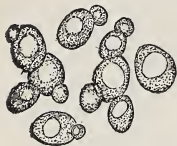


FIG. 275.—YEAST PLANTS.

containing abundant protoplasm and probably a nucleus, although the latter is not easily observed. It propagates rapidly by *budding*, which consists of the gradual extrusion of a wart-like swelling that is sooner or later cut off at the base by constriction, thus forming a separate organism. Although simple in structure, the yeast is found to be closely related to some of the higher groups of fungi as shown by the method of spore formation.

When grown on special substances like potato or carrot, the contents of the cell may *form spores inside of the sac-like mother cell*, thus resembling the sac-fungi to which blue mould and mildews belong. The yeast plant is remarkable on account of its power to induce alcoholic fermentation in the media in which it grows.

There are many kinds of yeasts. One of them is found in the common *yeast cakes*. In the process of manufacture of these cakes, the yeast cells grow to a certain stage, and the material is then dried and fashioned into small cakes, each cake containing great numbers of the yeast cells. When the yeast cake is added to dough, and proper conditions of warmth and moisture are provided, the yeast grows rapidly and breaks up the sugar of the dough into carbon dioxide and alcohol. This is *fermentation*. The gases escape and puff up the dough, causing the *bread to rise*. In this loosened condition the dough is baked; if it is not baked quickly enough, *the bread "falls."* Shake up a bit of yeast cake in slightly sweetened water: the water soon becomes cloudy from the growing yeasts.

*Parasitic fungi.*—Most of the moulds are saprophytes. Many other fungi are parasitic on living plants and animals (Fig. 285). Some of them have complicated life histories, undergoing many changes before the original spore is again produced. The *willow mildew* and the common *rust of wheat* will serve to illustrate the habits of parasitic fungi.

The *willow mildew* (*Uncinula salicis*).—This is one of the sac fungi. It forms white downy patches on the leaves of willows



(Fig. 276). These patches consist of numerous interwoven threads that may be recognized under the microscope as the mycelium of the fungus. The mycelium in this case lives on the surface of the leaf and nourishes itself by sending short branches into the cells of the leaf to absorb food materials from them.



FIG. 276. — COLONIES OF WILLOW MILDEW.

Numerous *summer-spores* are formed of short, erect branches all over the white surface. One of these branches is shown in Fig.

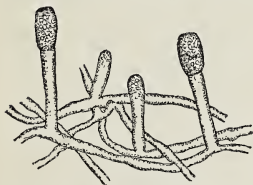


FIG. 277. — SUMMER-SPORES OF WILLOW MILDEW.

277. When it has grown to a certain length, the upper part begins to segment or divide into spores which fall and are scattered by the wind. Those falling on other willows reproduce the fungus there. This process continues all summer, but in the later part of the season provision is made to maintain the mildew through the winter. If some of the white patches are closely examined in July or August, a number

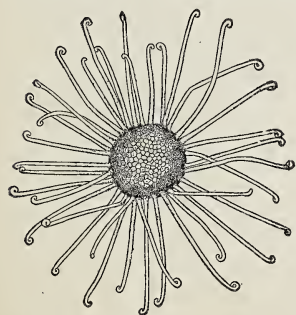


FIG. 278. — PERITHECIUM OF WILLOW MILDEW.

of little black bodies will be seen among the threads. These little bodies are called *perithecia*, shown in Fig. 278. To the naked eye they appear as minute specks, but when seen under a magnification of 200 diameters they present a very interesting appearance. They are hollow spherical bodies decorated around the outside with a fringe of crook-like hairs. The *resting-spores* of the willow mildew are produced in sacs or *asci* inclosed within the leath-

erly perithecia. Figure 279 shows a cross-section of a perithecium with the asci arising from the bottom. The spores remain securely

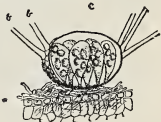


FIG. 279. — SECTION THROUGH PERITHECIUM OF WILLOW MILDEW.

packed in the perithecia. They do not ripen in the autumn, but fall to the ground with the leaf, and there remain securely protected among the dead foliage. The following spring they mature and are liberated by the decay of the perithecia. They are then ready to attack the unfolding leaves of the willow and repeat the work of the summer before.

*The wheat rust.*—The development of some of the rusts, as the common *wheat rust* (*Puccinia graminis*), is even more interesting and complicated than that of the mildews. Wheat rust is also a true parasite, affecting wheat and a few other grasses. The mycelium here cannot be seen by the unaided eye, for it consists of threads which are present within the host plant, mostly in the intercellular spaces. These threads also send short branches, or *haustoria* (Fig. 132), into the neighbouring cells to absorb nutriment.



FIG. 280.—SORI CONTAINING TELEUTOSPORES OF WHEAT RUST.

The *resting-spores* of wheat rust are produced in late summer, when they may be found in black lines breaking through the epidermis of the wheat stalk (black-rust stage). They are formed in masses, called *sori* (Fig. 280), from the ends of

numerous crowded mycelial strands just beneath the epidermis of the host. The individual spores are very small and can be well studied only with a microscope of high power ( $\times$  about 400). They are brown two-celled bodies with a thick wall (Fig. 281). Since they are the resting or winter-spores, they are termed *teleutospores* ("completed spores"). Usually they do not fall, but remain in the sori during winter. The following spring each cell of the teleutospore puts forth a rather stout thread, which does not grow more than several times the length of the spore and terminates in a blunt extremity. This germ tube, *promycelium*, now becomes divided into four cells by cross walls, which are formed from the top downwards. Each cell gives rise to a short, pointed branch which, in the course of a few hours, forms at its summit a single spore called a *sporidium*. This in turn germinates and produces a mycelium. In Fig. 282 a germinating teleutospore is drawn to show the promycelium, *p*, divided into four cells,



FIG. 281.—TELEUTOSPORE OF WHEAT RUST.

each producing a short branch with a little *sporidium*, *s.*

A most remarkable circumstance in the life history of the wheat rust is the fact that the mycelium produced by the sporidium *can live only in barberry leaves*, and it follows that if no barberry bushes are in the neighbourhood the sporidia finally perish. Those which happen to lodge on a barberry bush germinate immediately, producing a mycelium that enters the barberry leaf and grows within its tissues. Very soon the fungus produces a new kind of spores on the barberry leaves. These are called *æcidiospores*. They are formed in long chains in little fringed cups, or *æcidia*, which appear in groups on the lower side of the leaf (Fig. 283). These orange or yellow *æcidia* are termed *cluster-cups*. In Fig. 284 is shown a cross-section of one of the cups, outlining the long chains of spores, and the mycelium in the tissues.

The *æcidiospores* are formed in the spring, and after they have been set free, some of them lodge on wheat or other grasses, where they germinate immediately. The germ-tube enters the



FIG. 282. — GERMINATING TELEUTOSPORE OF WHEAT RUST.



FIG. 283. — LEAF OF BARBERRY WITH CLUSTER-CUPS.

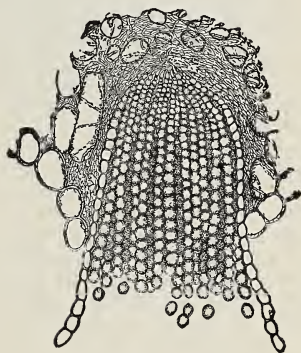


FIG. 284. — SECTION THROUGH A CLUSTER-CUP ON BARBERRY LEAF.

leaf through a stomate, whence it spreads among the cells of the wheat plant. In summer one-celled reddish *uredospores* ("blight spores," red-rust stage) are produced in a manner similar to the teleutospores. These are capable of germinating immediately,

and serve to disseminate the fungus during the summer on other wheat plants or grasses. Late in the season, teleutospores are again produced, completing the life cycle of the plant.

Many rusts besides *Puccinia graminis* produce different spore forms on different plants. The phenomenon is called *heteræcism*, and was first shown to exist in the wheat rust. Curiously enough, the peasants of Europe had observed and asserted that barberry bushes cause wheat to blight long before science explained the relation between the cluster-cups on barberry and the rust on wheat. The true relation was actually demonstrated, as has since been done for many other rusts on their respective hosts, by sowing the æcidiospores on healthy wheat plants and thus producing

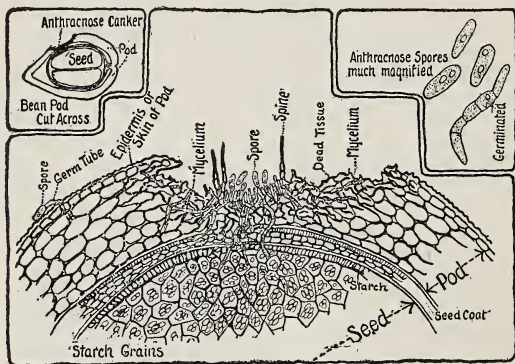


FIG. 285.—HOW A PARASITIC FUNGUS WORKS. Anthracnose on a bean pod entering the bean beneath. (Whetzel.)

the rust. The *cedar apple* is another rust, producing the curious swellings often found on the branches of red cedar trees. In the spring the teleutospores ooze out from the "apple" in brownish yellow masses. It has been found that these attack various fruit trees, producing æcidia on their leaves. Fig. 285 explains how a parasitic fungus works.

*Puffballs, mushrooms, toadstools, and shelf fungi.*—These represent what are called the *higher fungi*, because of the size and the complexity of the plant body as well as from the fact that they seem to stand at the end of one line of evolution. The mycelial threads grow together in extensive strands in rotten wood or in the soil, and send out large complex growths of mycelium in con-

nection with which the spores are borne. These aerial parts are the only ones which we ordinarily see, and which constitute the "mushroom" part (Fig. 131). Only asexual spores (*basidiospores*) are produced, and on short stalks (*basidia*) (Fig. 286). In the puffballs the spores are inclosed and constitute a large part of the "smoke." In the mushrooms and toadstools they are borne on *gills*, and in the shelf fungi (Fig. 134) on the walls of minute pores of the underside. The mycelium of these shelf fungi frequently lives and grows for a long time concealed in the substratum before the visible fruit bodies are sent out. Practically all timber decay is caused by such growth, and the damage is largely done before the fruiting bodies appear. For other accounts of mushrooms, see Chapter XIV.

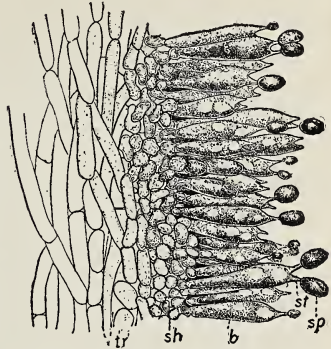


FIG. 286.—PART OF GILL OF THE CULTIVATED MUSHROOM.

*tr*, trama tissue; *sh*, hymenium; *b*, basidium; *st*, sterigma; *sp*, spore. (Atkinson.)

## LICHENS

Lichens are so common everywhere that the attention of the student is sure to be drawn to them. They grow on rocks, trunks of trees (Fig. 287), old fences, and on the earth. They are thin, usually gray ragged objects, apparently lifeless. Their study is too difficult for beginners, but a few words of explanation may be useful.

Lichens were formerly supposed to be a distinct or separate division of plants. They are now known to be organisms, each species of which is a constant association of a fungus and an alga. The thallus is ordinarily made up of fungous mycelium or tissue within which the imprisoned alga is definitely distributed. The result is a growth unlike either component. This association of

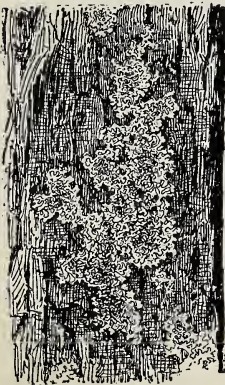


FIG. 287.—LICHEN ON AN OAK TRUNK. (A species of *Physcia*.)



alga and fungus is usually spoken of as *symbiosis*, or mutually helpful growth, the alga furnishing some things, the fungus others, and both together being able to accomplish work that neither could do independently. By others this union is considered to be a mild form of parasitism, in which the fungus profits at the expense of the alga. As favourable to this view, the facts are cited that each component is able to grow independently, and that under such conditions the algal cells seem to thrive better than when imprisoned by the fungus.

Lichens propagate by means of *soredia*, which are tiny parts separated from the body of the thallus, and consisting of one or more algal cells overgrown with fungus threads. These are readily observed in many lichens. They also produce spores, usually ascospores, which are always the product of the fungus element, and which reproduce the lichen by germinating in the presence of algal cells, to which the hyphæ immediately cling.

Lichens are found in the most inhospitable places, and, by means of acids which they secrete, they attack and slowly disintegrate even the hardest rocks. By making thin sections of the thallus with a sharp razor and examining under the compound microscope, it is easy to distinguish the two components in many lichens.

### LIVERWORTS

The liverworts are peculiar flat green plants usually found on wet cliffs and in other moist, shady places. They frequently occur in greenhouses where the soil is kept constantly wet.



FIG. 288.



FIG. 289.

#### PLANTS OF MARCHANTIA.

One of the commonest liverworts is *Marchantia polymorpha*, two plants of which are shown in Figs. 288, 289. The plant consists of a ribbon-like thallus that creeps along the ground, becoming repeatedly forked as it grows. The end of each branch



is always conspicuously notched. There is a prominent midrib extending along the centre of each branch of the thallus. On the under side of the thallus, especially along the midrib, there are numerous rhizoids which serve the purpose of roots, absorbing nourishment from the earth and holding the plant in its place. The upper surface of the thallus is divided into minute rhombic areas that can be seen with the naked eye. Each of these areas is perforated by a small breathing pore or stomate that leads into a cavity just beneath the epidermis. This space is surrounded by chlorophyll-bearing cells, some of which stand in rows from the bottom of the cavity (Fig. 290). The delicate assimilating tissue is thus brought in close communication with the outer air through the pore in the thick, protecting epidermis.

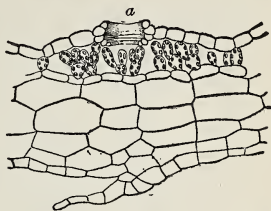


FIG. 290. — SECTION OF THALLUS OF MARCHANTIA. Stomate at *a*.

At various points on the midrib are little cups containing small green bodies. These bodies are buds or *gemmae* which are outgrowths from the cells at the bottom of the cup. They become loosened and are then dispersed by the rain to other places, where they take root and grow into new plants.

The most striking organs on the thallus of marchantia are the peculiar stalked bodies shown in Figs. 288, 289. These are termed *archegoniophores* and *antheridiophores* or *receptacles*. Their structure and function are very interesting, but their parts are so minute that they can be studied only with the aid of a microscope magnifying from 100 to 400 times. Enlarged drawings will guide the pupil.

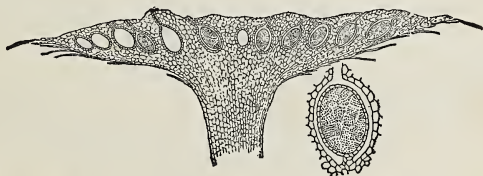


FIG. 291. — SECTION THROUGH ANTHERIDIOPHORE OF MARCHANTIA, showing antheridia. One antheridium more magnified.

The *antheridiophores* are fleshy, lobed disks borne on short stalks (Fig. 291). The upper surface of the disk shows openings scarcely visible to the naked eye. However, a section of the disk, such as is drawn in Fig. 291, shows that the pores lead into oblong cavi-

ties in the receptacle. From the base of each cavity there arises a thick, club-shaped body, the *antheridium*. Within the antheridium are formed many sperm-cells which are capable of swimming about in water by means of long lashes or cilia attached to them. When the antheridium is mature, it bursts and allows the ciliated sperm cells to escape.



FIG. 292. —  
ARCHEGO-  
NIUM OF  
MARCHANTIA.

The *archegoniophores* are also elevated on stalks (Fig. 289). Instead of a simple disk, the receptacle consists of nine or more finger-like rays. Along the under side of the rays, between delicately fringed curtains, peculiar flask-like bodies, or *archegonia*, are situated. The archegonia are not visible to the naked eye. They can be studied only with the microscope ( $\times$  about 400). One of them much magnified is represented in Fig. 292. Its principal parts are the long *neck*, *a*, and the rounded *venter*, *b*, inclosing a large free cell—the egg-cell.

We have seen that the antheridium at maturity discharges its sperm-cells. These swim about in the water provided by the dew and rain. Some of them finally find their way to the archegonia and egg-cells, the latter being fertilized, as pollen fertilizes the ovules of higher plants.

After fertilization the egg-cell develops into the spore capsule or *sporogonium*. The mature spore capsules may be seen in Fig. 293. They consist of an oval spore-case on a short stalk, the base of which is imbedded in the tissue of the receptacle, from which it derives the necessary nourishment for the development of the sporogonium. At maturity the sporogonium is ruptured at the apex, setting free the spherical spores together with numerous filaments having spirally thickened walls (Fig. 294). These filaments are called *elaters*. When drying, they exhibit rapid movements by means of which the spores are scattered. The spores germinate and again produce the thallus of marchantia.



FIG. 293. — ARCHE-  
GONIOPHORE,  
WITH SPORO-  
GONIA, OF MAR-  
CHANTIA.

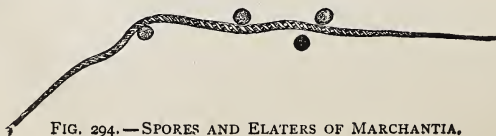


FIG. 294. — SPORES AND ELATERS OF MARCHANTIA.

## MOSSES (Bryophyta)

If we have followed carefully the development of marchantia, the study of one of the mosses will be comparatively easy. The mosses are more familiar plants than the liverworts. They grow on trees, stones, and on the soil in both wet and dry places. One of the common larger mosses, known as *Polytrichum*

*commune*, may serve as an example, Fig. 295. This plant grows on rather dry knolls, mostly in the borders of open woods, where it forms large beds. In dry weather these beds have a reddish brown appearance, but when moist they form beautiful green cushions. This colour is due, in the first instance, to the colour of the old stems and leaves, and, in the second instance, to the peculiar action of the green living leaves under the influence of changing moisture-conditions. The inner or upper surface of the leaf is covered with thin, longitudinal ridges of delicate cells which contain chlorophyll. These cells are shown in cross-section in Fig. 296, as dots or granules. All the other

tissue of the leaf consists of thick-walled, corky cells which do



FIG. 295. — *POLYTRICHUM COMMUNE*.

*f, f*, fertile plants, one on the left in fruit;  
*m*, antheridial plant.



FIG. 296. — SECTION OF LEAF OF *POLYTRICHUM COMMUNE*.

not allow moisture to penetrate. When the air is moist the green leaves spread out, exposing the chlorophyll cells to the air, but in

dry weather the margins of the leaves roll inward, and the leaves fold closely against the stem, thus protecting the delicate assimilating tissue.

The *antheridia* and *archegonia* of *polytrichum* are borne in groups at the ends of the branches on different plants (many mosses bear both organs on the same branch). They are surrounded by involucre of characteristic leaves termed *perichætia* or *perichætal leaves*. Multicellular hairs known as *paraphyses* are scattered among the archegonia and antheridia. The involucre with the organs borne within them are called *receptacles*, or, less appropriately, "moss flowers." As in *marchantia*, the organs are very minute and must be highly magnified to be studied.

The antheridia are borne in broad cup-like receptacles on the antheridial plants (Fig. 297). They are much like the antheridia



FIG. 297. — SECTION THROUGH A RECEPTACLE OF *POLYTRICHUM COMMUNE*, showing paraphyses and antheridia.

of *marchantia*, but they stand free among the paraphyses and are not sunk in cavities. At maturity they burst and allow the sperm cells or *spermatozoids* to escape. In *polytrichum*, when the receptacles have fulfilled their function, the stem continues to grow from the centre of the cup (*m*, Fig. 295). The archegonia are borne in other receptacles on different plants. They are like

the archegonia of *marchantia* except that they stand erect on the end of the branch.

The *sporogonium* which develops from the fertilized egg is shown in *a*, *b*, Fig. 295. It consists of a long, brown stalk bearing the spore-case at its summit. The base of the stalk is imbedded in the end of the moss stem by which it is nourished. The capsule is entirely inclosed by a hairy cap, the *calyptra*, *b*. The calyptra is really the remnant of the archegonium, which, for a time, increases in size to accommodate and protect the young growing capsule. It is finally torn loose and carried up on the spore-case. The mouth of the capsule is closed by a circular lid, the *operculum*, having a conical projection at the centre.

The operculum soon drops, or it may be removed, displaying a fringe of sixty-four teeth guarding the mouth of the capsule. This ring of teeth is known as the *peristome*. In most mosses the teeth exhibit peculiar hygroscopic movements; *i.e.* when moist they bend outwards, and upon drying curve in toward the mouth of the capsule. This motion, it will be seen, serves to disperse these spores gradually over a long period of time.

Not the entire capsule is filled with spores. There are no elaters, but the centre of the capsule is occupied by a columnar

strand of tissue, the *columella*, which expands at the mouth into a thin, membranous disk, closing the entire mouth of the capsule except the narrow annular chink guarded by the teeth. In this moss the points of the teeth are attached to the margin of the membrane, allowing the spores to sift out through the spaces between them.

When the spores germinate they form a green, branched thread, the *protonema*. This gives rise directly to moss plants, which appear as little buds on the thread. When the moss plants have sent their little rhizoids into the earth, the protonema dies, for it is no longer necessary for the support of the little plants, and the moss plants grow independently.

*Funaria* is a moss very common on damp, open soil. It forms green patches of small fine leaves from which arise long brown stalks terminated by curved capsules (Fig. 298). The structure is similar to that of *polytrichum*, except the absence of plates on the under side of the leaves, the continuous growth of the stem, the curved capsule, double peristome, monœcious rather than dioecious receptacles, and nearly glabrous unsymmetrical calyptra.



FIG. 298. — *FUNARIA HYGROSOPICA*.

## EQUISETUMS, OR HORSETAILS (Pteridophyta)

There are about twenty-five species of equisetum, constituting the only genus of the unique family *Equisetaceæ*. Among these *E. arvense* (Fig. 299) is common on clayey and sandy soils.

In this species the work of nutrition and that of spore production are performed by separate shoots from an underground rhizome. The fertile branches appear early in spring. The stem, which is 3 to 6 inches high, consists of a number of cylindrical, furrowed internodes, each sheathed at the base by a circle of scale leaves. The shoots are of a pale yellow colour. They contain no chlorophyll, and are nourished by the food stored in the rhizome (Fig. 299).

The spores are formed on specially developed fertile leaves or *sporophylls* which are collected into a spike or cone at the end of the stalk (*a*, Fig. 299). A single sporophyll is shown at *b*. It consists of a short stalk expanded into a broad, mushroom-like head. Several large *sporangia* are borne on its under side. The spores formed in the sporangia are very interesting and beautiful



objects when examined under the microscope ( $\times$  about 200). They are spherical, green bodies, each surrounded by two spiral bands attached to the spore at their intersection, *s*. These bands exhibit hygroscopic movements by means of which the spores become entangled, and are held together. This is of advantage to the plant, as we shall see. All the spores are alike, but some of the *prothallia* grow to a greater size than the others. The large prothallia produce only *archegonia* while the smaller ones produce *antheridia*. Both these organs are much like those of the ferns, and fertili-



FIG. 299. — *EQUISETUM ARVENSE*.

*st*, sterile shoot; *f*, fertile shoot showing the spike at *a*; *b*, sporophyll, with sporangia; *s*, spore.

zation is accomplished in the same way. Since the prothallia are usually dioecious, the special advantage of the spiral bands, holding the spores together so that both kinds of prothallia may be in close proximity, will be easily understood. As in the fern, the fertilized egg-cell develops into an equisetum plant.

The sterile shoots (*st*, Fig. 299) appear much later in the season. They give rise to repeated whorls of angular or furrowed branches. The leaves are very much reduced scales, situated at the internodes. The stems are provided with chlorophyll and act as assimilating tissue, nourishing the rhizome and the fertile shoots. Nutrient is also stored in special tubers developed on the rhizome.



Other species of *equisetum* have only one kind of shoot—a tall, hard, leafless, green shoot with the spike at its summit. *Equisetum* stems are full of silex, and they are sometimes used for scouring floors and utensils; hence the common name “scouring rush.”

### ISOËTES (Pteridophyta)

*Isoëtes* or quillwort is usually found in water or damp soil on the edges of ponds and lakes. The general habit of the plant is seen in Fig. 300, *a*. It consists of a short, perennial stem bearing numerous erect, quill-like leaves with broad sheathing bases. The plants are commonly mistaken for young grasses.

*Isoëtes* bears two kinds of spores, large roughened ones, the *macrospores*, and small ones or *microspores*. Both kinds are formed in *sporangia* borne in an excavation in the expanded base of the leaf. The macrospores are formed on the outer and the microspores on the inner leaves. A sporangium in the base of a leaf is shown at *b*. It is partially covered by a thin membrane, the *velum*. The minute triangular appendage at the upper end of the sporangium is called the *ligule*.

The spores are liberated by the decay of the sporangia. They form rudimentary prothallia of two kinds. The microspores produce prothallia with *antheridia*, while the macrospores produce prothallia with *archegonia*. Fertilization takes place as in the mosses or liverworts, and the fertilized egg-cell, by continued growth, gives rise again to the *isoëtes* plant.

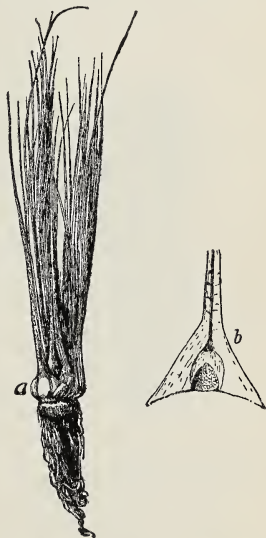


FIG. 300. — ISOËTES, showing habit of plant at *a*; *b*, base of leaf, showing sporangium, velum, and ligule.

### CLUB-MOSSES (Pteridophyta)

The club-mosses are low trailing plants of moss-like looks and habit, although more closely allied to ferns than to true mosses. Except one genus in Florida, all the club mosses belong to the

genus *Lycopodium*. They grow mostly in woods, having 1-nerved evergreen leaves arranged in four or more ranks. Some of them make long strands, as the ground pine, and are much used for Christmas decorations. The spores are all of *one kind* or form, borne in *1-celled sporangia* that open on the margin into *two valves*. The sporangia are borne in some species (Fig. 301)



FIG. 301. — A LYCOPODIUM WITH SPORANGIA IN THE AXILS OF THE FOLIAGE LEAVES. (*Lycopodium lucidulum*.)



FIG. 302. — A CLUB-MOSS (*Lycopodium complanatum*).

as small yellow bodies in the axils of the ordinary leaves near the tip of the shoot; in other species (Fig. 302) they are borne in the axils of small scales that form a catkin-like spike. The spores are very numerous, and they contain an oil that makes them inflammable. About 100 species of lycopodium are known. The plants grown by florists under the name of lycopodium are of the genus *Selaginella*, more closely allied to isoëtes, bearing two kinds of spores (microspores and macrospores).

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Additional material to be studied after Morphology, etc., between Chapters XII and XIII

### FOOD STORAGE IN PLANTS ✓

**Storehouses**—All greatly thickened parts of plants are depositories for the storage of food. This food is mostly sugar or starch. Potatoes, beets, turnips, rhizomes or root stalks and seeds are examples. This store of plant food enables the plant to start more quickly in the spring without waiting for the food elaboration to begin in the leaves, and it enables the plantlet (embryo) in the seed to grow until it has established itself in the earth. The flowers of early blooming trees are developed mostly from the nourishment stored in the twigs, not from the material taken in at the time, by the roots, nor from food being made by the newly forming leaves. This can be shown by bringing branches of early blooming plants into the house in the winter and keeping them in water. They will blossom and in some cases even develop leaves.

**Food Storage in Roots**—Many roots contain large quantities of plant food, usually in the form of starch, sugar or proteids, or all three together. The fleshy tap roots of parsnips, carrots, sweet potatoes, and turnips are good examples. Beet roots contain so much sugar that a large part of the sugar supply of Europe and even of Canada is obtained from them. Very often roots have a bitter taste, as in the case of the chicory, dandelion, rhubarb, and others like the monkshood, jasmine, and pinkroot are poisonous. Evidently the plant may be benefitted by the disgusting odor or taste, or poisonous nature of its roots, which render them uneatable.

**Biennial** plants like the beet, carrot, etc., do not produce seeds until the second summer that they are planted, the first season's work consisting mainly in producing the food that is stored in the roots. To this storage is due their fleshy appearance. If the root is planted the following spring it feeds the rapidly growing stem, and an abundant crop of flowers and seeds follows, while the root will be found to have withered with its store of food quite exhausted. Many of the *Perennials*, e.g., plants that live for many years like the rhubarb, etc., die to the ground at the beginning of winter and in the spring make a rapid growth from the materials laid up in the roots.

**Food Storage in Stems**—The foregoing explains why plants store food. Probably the best example of food storage in the stem is the sago palm, which contains sometimes up to eight hundred (800) pounds of starchy material in a single stem. The common plants of the temperate zone furnish a large number of examples of food deposits in stems. The branches and trunk of a tree furnish the most convenient place in which to deposit food to begin the growth in the following spring.

Many plants die down to the ground at the beginning of winter; the storage, therefore, must be either in the roots or the *underground portions of the stems*. Some plants seem to have developed special types of underground stems, such as rootstocks, tubers, and bulbs to act as storehouses through the winter or in some countries in the dry seasons. The commonest tuber is the potato; it also shows one of the most specialized forms for the purpose of food storage.

The Potato is a very highly modified stem. The corky layer of the bark is well represented, and so is the loose cellular layer beneath it. There is practically no wood. but pith constitutes the main part of the tuber. The reason for this is that the tuber buried in and supported by the earth does not require strength giving tissue, but the kind that is well adapted to the storage of food.

(1) Potatoes are not borne on true roots, but on underground branches.

(2) Their surface is covered with a number of small dots like the bark of a young tree; these are lenticels or breathing pores.

(3) The eye is in the axil of a small scale which represents a leaf.

(4) The eyes of the potato are the rudimentary leaves and buds.

The four characteristics just mentioned are ample proof that potatoes are stems and not roots.

Some botanists classify tubers as (1) stem tubers as the potato; and (2) root tubers as the sweet potato. Many tubers are stem at the top and root in the remaining part. These are called crown-tubers, because the upper part comes to the surface of the ground, or is a crown. Leaves and stems grow from this upper part as in beets, carrots, turnips, etc., but most botanists classify these crown tubers as "Fleshy Roots".

**Bulbs** are of two kinds: the scale bulbs, e.g., the lily, and the coated or tunicated bulbs (made up of layers within

layers) as onions or hyacinths. Bulbs, whether coated or scaly, are merely very short and stout underground stems covered closely with scales or layers which represent leaves or the bases of leaves.

Small bulbs borne on the foliage or flowers are known as bulblets. The top onions and tiger lily are of this type. Bulbs that grow around the main bulb, or which are formed by the breaking apart of the bulb are known as bulbels. The multiplier or potato onion is an example. If this bulb is cut across, it is found to have two or more hearts or cores. When planted, as many onions grow as there are cores.

**Food Storage in Leaves**—Our best example of this is the century plant which stores food in the leaves for fifteen years or more and uses this food to produce an immense flowering shoot. This may reach a height of 30 feet and a weight of 500 lbs. After the seeds are ripened, the leaves are found to have lost 90% of their weight. In this case both the plant food and water required are furnished by the leaves. Fleshy leaves of any kind contain a great deal of stored food and also stored water in the form of a mucilage like material.

*(Laboratory work)*

(a) *Starch*—Place some iodine solution on laundry starch. Note the change which occurs. Now cut kernels of the grains and potatoes into pieces and drop iodine solution on them. What occurs? What is your conclusion?

(b) *Proteids*—Nitric acid burns proteids yellow. Ammonia intensifies this color. Cut sections of corn, wheat, beans, etc.; put in a dish and add nitric acid solution and ammonia. What do you find? What does this indicate?

(c) *Oils*—Crush some kernels of English walnuts or peanuts on white paper. Heat for short time. What do you notice on the paper? Conclusions? Test ground corn in the same way.

(d) *Sugar* (reduction of fruit sugar)—Squeeze a few drops of grape juice into a test-tube containing 100 c.c. of Fehling's solution; heat. A dark yellow to reddish precipitate indicates the presence of sugar. Test the juice of other fruits.

*Note*—Fehling's Solution:—

(a) Copper Sulphate 35 grams in 500 c.c. of water.

(b) Rochelle salts 173 grams and Sodium Hydroxide 50 grams in 500 c.c. of water.

Keep separately and mix in equal quantities when required.

### \*†PHANEROGAMS (phenogams)

#### Leguminosae—Sweet Pea

(*Laboratory work*)—Each pupil to have a flower of the sweet pea.

Give a short description of the size, shape and color of this flower. What is the color of the lowest or outermost part of the flower? Is it all of one piece? Is it the same shape all the way up from the base? If it ends in several pieces (lobes) are they all the same size? How many? Pull off calyx, split down one side, flatten it out, and press and preserve it. How many petals has this flower? How are they placed with respect to the calyx lobes? Is the corolla regular or irregular? Remove the petals carefully. Make drawings of them in their relative positions. Are any of them made up of two smaller petals grown together? Which? Give reasons for your answer. What insect does the blossom resemble? What name do we give blossoms of this shape? How many stamens has the sweet pea? What is peculiar about their structure and arrangement? Are the stamens inserted on the receptacle or on the calyx? What is the scientific name for this mode of attachment? From some of the riper flowers you may obtain a yellow powder or dust. What is this? Make a drawing of the stamen and name its parts. Note the structure of the outer end of the young pod. Why has it this structure? What is the name of this outer end? Of the pod itself? Of the part connecting the two? How many cells in the ovary?

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\*To be studied after Chapter V and in connection with Chapter XVIII.

†For explanation of Phanerogam, see Botany, page 180.

A table giving the summary of an investigation as the above is called a—*Schedule of the Flower*.

Organ	No.	Cohesion	Adhesion	Remarks
Calyx		Gamosepalous	Inferior	
Sepals	5			
Corolla		Papilionaceous irregular	Perigynous	The two front petals united.
Petals	5			
Stamens	10	Diadelphous	Perigynous	
Filaments				
Antlers				
Pistil		Apocarpous		
Carpels	1			
Ovary			Superior	

Many plants, such as the clovers, vetch, caragana, etc., have the same structure of their flowers and are grouped into one large family or order, viz., The Leguminosae.

The characteristics of this order are: The plants are either herbs, shrubs, or trees with alternate, stipulate, compound leaves and irregular flowers; calyx 5-parted; corolla of 5 petals, the upper or standard larger than the others, and enclosing them in the bud and later spreading, the whole forming a papilionaceous corolla; stamens usually 10, and arranged in groups of 9 and 1, but sometimes distinct or all joined together; ovary 1-celled, forming a legume in fruit.

### Cruciferae—Mustard

Examine the flower of the mustard and compare with the flower of the sweet pea. How are the flowers arranged on the plant? How many sepals? Are they gamosepalous or polysepalous? Give their size, shape and color. How many petals? Are they separate? Are they all the same size and shape. Give their insertion with reference to the sepals. Make a drawing of one. How many stamens? Are they all alike in size and shape? Explain. Are they all inserted on the same circle? Describe one of the riper pods. How many cells in it? Draw a floral diagram of the mustard.



*Schedule of the Mustard Flower*

Organ	No.	Cohesion	Adhesion	Remarks
Calyx		Polysepalous	Inferior	
Sepals	4			
Corolla		Polypetalous	Hypogynous	
Petals	4			
Stamens	6	Tetradynamous	Hypogynous	Two sepals with a pair of long stamens opposite each; the other two with one short stamen opposite each.
Filaments	6			
Antlers	6			
Pistil		Syncarpous		Pistil wing margined, deeply notched at the top.
Carpels	2		Superior	
Ovary				

Other plants that have flowers similar to those of the mustard are shepherd's purse, radish, water cress, etc. These plants belong to the order *Cruciferae*, the characteristics of which are:—

Herbs with pungent juice.

Leaves alternate, exstipulate.

Inflorescence, racemes or corymbs, usually without bracts.

Flower, regular, hypogynous.

Sepals, 2+2, polysepalous.

Petals 4, polysepalous.

Stamens 2+4, two short and four long.

Carpels, 2, syncarpous; ovary divided; ovules numerous.

Fruit usually a silique or silicle.

Seed, no endosperm.

**Other seed plants**

A study should be made of representatives of seed plants of the locality using a similar method as in the case of the Pea and the Mustard. The *Compositae* is described on pages 140 to 142 of this book. The *Gymnosperms* are plants in which the ovules and seeds are naked and fertilized by the direct application of the pollen. The order *Coniferae* belongs to this sub-class of the *Dicotyledons*. The pine and spruce are examples. The other sub-class of the *Dicotyledons* are the *Angiosperms*, which have their seeds enclosed in a seed-vessel or pericarp. Typical orders beside the *Leguminosae*, *Cruciferae* and *Compositae* are:

Order	Species
Ranunculaceae...	Pasque flower, Buttercup, Columbine, Marsh Marigold.
Rosaceae.....	Prairie rose, strawberry, cherry silver weed.
Umbelliferae.....	Water Parsnip, carrot, caraway.
Labiatae.....	Wild Bergamot, Mint, Sage, False Dragon-head.

The commonest varieties of mono-cotyledons are the *Gramineae* to which all our grains and groves belong; and the *filiaceae* of which the Wild Onion and Tiger Lily are examples.

Beside the flower itself, in making a study of a plant, the following should be determined:—

General appearance..	Tree, shrub or herb.
Root.....	Tap or fibrous.
Stem.....	Kind, position, shape, covering, color.
Leaf.....	Kind, position or arrangement, shape, margin, surface.
Inflorescence.....	Definite or indefinite, kind.
Fruit.....	Dry or fleshy, dehiscence, kind, color.
Preferred habitat....	Conditions under which it grows.
Remarks.....	Anything characteristic, not included in the above.

## ECOLOGY

Chapter IV gave a general idea of Plant Societies and ecology. This section is a systematized summary of those parts of the morphology and physiology, which may also be treated under the heading of ecology.

### Factors influencing plant life.

1. Water: (a) Water is necessary for all plants.  
(b) Aquatics need most.  
(c) Excess is injurious to some plants.
2. Light: (a) Necessary for the making of starch.  
(b) Determines the direction of growth.  
(c) Determines formation of suitable leaves.  
(d) Influences the structure of the leaf for—(1) direct ray,  
(2) shade.
3. Heat: (a) Influences the growth; limits approximately 32° F. to 123° F.  
(b) Influences distribution.

4. Wind: (a) Aids pollination.  
(b) Aids seed dispersal.  
(c) Injures by (1) rapid evaporation,  
(2) felling and breaking.
5. Snow (ground cover):  
(a) Prevents deep freezing.  
(b) Prevents alternate freezing and thawing.
6. Mulch (of soil or leaves, etc.):  
(a) Checks evaporation.
7. Chemical condition of the soil:  
(a) Alkaline—Permits a limited range of species.  
(b) Acid  
(c) Neutral.  
(d) Determines fertility.
8. Physical and Mechanical conditions of soil.  
(a) Influences the water supply (1) gravel is dry.  
(2) clay holds water better.  
(b) Influences the temperature.  
(c) Influences the air supply.  
(d) Influences the amount of plant food,
9. Animals:  
(a) Aid pollination.  
(b) Aid seed dispersal.  
(c) Sometimes they injure.
10. Plants:  
(a) Cause decay or disease (fungi and mushrooms).  
(b) Soil bacteria—(1) beneficial.  
(2) harmful.

## Typical Plant Societies

Plant societies are usually classified according to location. Thus we speak of (1) Roadside, (2) Fence corner, (3) Prairie, (4) Desert, (5) Slough, (6) Garden, (7) Shore, (8) Rock, (9) Forest societies.

- 1 and 2. *Roadside Society*: Grasses and perennial weeds near the fences, and different weeds near the wagon track, due to seeds falling from vehicles. They may be hydrophytes or xerophytes, depending on the situation.
3. *Prairie Society*: Here grasses predominate, and we find also sage brush, aster, golden rod, yarrow, cactus, rose, thistle, willow, etc.

5. *Slough Society*: Pond lilies, wild rice, cat tail, rushes, sedge, grass bladderwort, water buttercup, moss, sweet coltsfoot, willows, etc.
6. *Garden Society*: This is a culture society, consisting of vegetables or flowers, and having a few (or more often many) weeds intermingled. Each kind of weed seems to have its own way or adaptation for crowding out the cultivated plants. Some produce many seeds, others grow more rapidly, etc., than the flowers or vegetables.
7. *Shore Society*: These are very wet part of the time and very dry part. Name some plants that would live under such conditions.
8. *Rock Society*: Here the vegetation is usually low, matted, and is of plants with thick leaves, or mosses or lichens.
9. *Forest Society*: Here we find trees which need a medium amount of water; also shade-loving plants, on the floor of the forest.

### Plant Societies on the basis of water supply.

- ✓(1) *Xerophytes*—Plants that are adapted to live where water is scarce.
- (2) *Hydrophytes*—Plants adapted to live where water is plentiful.
- ✓(3) *Mesophytes*—Plants that tolerate a moderate supply of water.
- (4) *Halophytes*—Plants that tolerate salt water.
- (5) *Tropophytes*—Plants that are xerophytes part of the year and hydrophytes or mesophytes the other part.

Note that "water" means available water in the soil, as frost, salt or humic acid in a bog may prevent the plants using the water.

### Adaptations which fit Xerophytes to their environment.

- (1) Reduction in surface, as small leaves, cactus, etc.
- (2) Small spaces between cells in leaves (small space, therefore less air saturated, therefore less water is lost).
- (3) Increase in number of vessels to convey water up from the roots.
- (4) Lengthening of palisade cells.
- (5) Increase in thickness of cutin (or outer surface of leaves).
- (6) Stomata at the bottom of pits or hollows in the leaf.
- (7) Leaves covered with hairs.
- (8) Leaves curl under to cover the stomata.
- (9) Special water-storing cells, or mucilage cells (Live-for-ever).
- (10) Compact growth, as a mat on the ground, prevents evaporation.
- (11) Tap roots.
- (12) Leaves in rosettes, as thistle, shepherd's purse.

## Habitats of Xerophytes.

- (1) Deserts—(a) water wanting, (b) alkaline.
- (2) On trees or rocks as lichens.
- (3) Sandy soil.
- (4) Sea shores (Halophytes grow there).
- (5) Peat bogs.
- (6) Polar zones and mountain heights.

## Adaptations of Hydrophytes.

- (1) Poorly developed root system.
- (2) In pure aquatics, no root-hairs and few roots.
- (3) Elongated stem or axis, also petioles.
- (4) Small amount of wood or supporting tissue, as the water buoys up the plant, few vessels needed to convey water. In land hydrophytes the softer tissue is full of water and this supports it. (*Nasturtium*).
- (5) Abundance of air spaces. In immersed plants nearly all the stem is air space, but in such as the cat-tails there is not so much air space.
- (6) Leaves of large area, large thin leaves, leaves much dissected.
- (7) Stomata on the side exposed to the air, or even wanting.
- (8) Some plants have water stomata in the main ends of the leaves, which cannot close. (*Nasturtium*.)
- (9) Some grasses have a thin epidermis which bursts with the pressure from within. (Some of the dew is due to this.)
- (10) Stomata is not guarded.
- (11) Water glands in tropical hydrophytes which gather excess of water and secrete it.

*Mesophytes* include: Deciduous forests, meadows, pastures, prairies, weeds, etc.

*Tropophytes* are in summer either mesophytes or hydrophytes, and in winter xerophytes. They have broad leaves as our deciduous trees, also the shepherd's purse.

## GENERAL BOTANY

### 1. Plant selection and improvement.

As plants are of primary importance to man, in furnishing him with the greater part of his food, clothing and shelter, he naturally selected for cultivation those which furnished

him these necessities. In selecting always those species which suited his purpose the best, he eventually developed species quite different from the parent plant. We have historic record that the Chinese practised this method of improving their plants 4,300 years ago. But it is only in the last century that the scientific foundations of this process have been found out. In the first two chapters we referred to variation, the struggle for existence, natural and artificial selection, and plant breeding, in the form of an introduction to the study of botany. We should now endeavor to apply our knowledge of plant morphology, physiology and ecology to these processes.

The foundation of all plant improvement is *variation*, that is, that no two plants or parts of plants are exactly alike. Five hundred beans were taken at random from a large lot and compared as to size. The following table shows the result:

8 mm. long	1 bean	13 mm. long	118 beans
9 " "	3 beans	14 " "	37 "
10 " "	26 "	15 " "	9 "
11 " "	120 "	16 " "	1 bean
12 " "	185 "		

Similar studies have been made relative to the height of man, the yield of wheat, the milk production of cows, the weight of potatoes, etc. In every case the result was similar. In other words, the great majority of living things of the same variety are nearly alike. But there are a few extremes above and below the average. Approximately the centre individual shows the average characteristics of the whole group. After its discoverer this semi-mathematical basis of variation is known as Galton's law.



The existing species of wild plants are the ones which during ages of struggle for existence best adapted themselves to their environment. They are the ones that nature selected as the fittest to survive, hence the expression, "survival of the fittest" and "natural selection."

When the botanist or agriculturist selects plants to be used for his own purposes, he merely imitates nature and the process of so doing is known as *artificial selection*. Up to about sixty years ago the *improvement of plants* consisted of (1) selecting plants having some desired characteristics, such as size, shape, color, yield, etc., and reproducing them; (2) continuing this process under suitable environment until the variety was thoroughly established. It has been found that environment, such as climate, soil, etc., will emphasize some and repress other characters of plants, and this fact was also utilized in bettering quantity and quality.

## 2. Heredity.

As we already have observed, plants may be reproduced otherwise than from seeds, that is by rootstocks, tubers, stems, leaves, etc. Such reproduction is without sex and is therefore called *asexual*. As there is no chance of outside interference, plants so reproduced always come true to type and variety.

Plants reproduced from seed, that is due to the union of two units of protoplasm (gametes) have a *sexual* reproduction. Obviously in close fertilized plants the offspring will be exceedingly similar to the parent plant. Not so, however, in cross-fertilized plants. There a large number of variations are possible. It was the Czecho-Slovakian

priest, Gregor Mendel, who first determined the laws underlying these variations, the relation between parent and offspring, in short, the principles of heredity.

In order to account for the large number of variations among his garden peas Mendel resorted to artificial crossing or *hybridizing*. (The process is described on pages 153 and 154.) He used yellow seeded and green seeded, tall and dwarf seeded, smooth seeded and wrinkled seeded plants, beside four other pairs of characters in his experiments, which lasted for eight years. The result can be best shown in a diagram, in which we will assume four individuals for each generation. Of course, the number of seeds and resulting plants were a great deal larger. The "four" is used to give the proportion of each type reproduced.

Supposing red and white flowers have been crossed, the results would be seemingly all red or red hybrids. Now let us take the offsprings from one of this hybrid:

First Generation	Second Generation	Third Generation	Fourth Generation
		Pure red	All red
	Pure red	Pure red	All red
		Pure red	All red
		Pure red	All red
	Red hybrid	Pure red	All red
		Red hybrid	$\frac{1}{4}$ red, $\frac{1}{4}$ white
		Red hybrid	$\frac{1}{4}$ red hybrid
		Pure white	All white
		Pure red	All red
		Red hybrid	$\frac{1}{4}$ red, $\frac{1}{4}$ white
Red hybrid	Red hybrid	Red hybrid	$\frac{1}{4}$ red hybrid
		Pure white	All white
		Pure white	All white
		Pure white	All white
	Pure white	Pure white	All white
		Pure white	All white

Mendel found that in the first generation the characters did not blend. He did not get pink or half wrinkled, etc., peas. They all resembled one parent. The results were: yellow seeded, tall, smooth seeded, red, etc., peas, though he crossed them with green seeded, dwarf, wrinkled seeded, white flowered, etc., plants. Evidently, where two characters of a pair meet in an individual one of them marks or dominates over the other one. This is known as (1) *the law of dominance*. The evident characters are called dominant and those masked recessive.

The generations developing from the hybrids showed one-fourth of them resembling the maternal grandparent type, one-fourth the paternal grandparent type and the remainder were hybrids. The hybrid does not reproduce itself in offsprings all having the same characteristics, but has a tendency to revert to parent types. This fact is known as (2) *the law of segregation*.

While each pair of alternative characters behave according to the two laws just mentioned, one must bear in mind that plants and animals are made up of a large number of differing characters. Thousands of experiments have been made and it has been found that each pair of characters acts independently of every other pair. This is known as (3) *the law of unit characters*. Obviously the larger the number of characters, the greater the possible number of combinations and hence the immense diversity among the individuals of the same species.

The laws of dominance, segregation, and unit characters, are the principles of heredity and are named after their discoverer, Mendel's Laws.

### Practical Application

Technical Agriculturists apply the laws of selection and heredity to the improvement of crops and animals.

(a) They increase variation, either by changing the environment or by crossing, or by both.

(b) From the large number of variations they select those individuals or groups with desirable characteristics.

(c) Test the power of the selected individuals to reproduce their desirable characteristics.

(d) Maintain the improved type by constant selection, suitable environment and breeding only with desired types.

## GLOSSARY

*accessory* or *reinforced fruits* are those in which the ripened pericarp is combined with other parts, as with the torus or the calyx.

*adventitious*. Coming by chance or without order, as the sprouts that arise where a limb is cut off.

*aggregate fruits* are those in which several distinct pistils cohere to form one body, as in blackberry, raspberry, mulberry.

*akene* or *achene*. A one-seeded indehiscent fruit, usually small and seed-like.

*analogous*. Like to, in function or use. See *homologous*.

*anemophilous*. Said of flowers that are pollinated by the wind.

*annual*. A plant that naturally does not live more than one year, as garden bean, pea, Indian corn, buckwheat, cowpea.

*anther*. The knob or enlargement of the stamen, bearing the pollen.

*antheridium*. The male or sperm-cell organ, such as occurs on the prothallus of ferns and similar plants. See *archegonium*.

*apetalous*. Without petals.

*apical*. At the top.

*archegonium*. The female or egg-cell organ on the prothallus of ferns and related plants. See *antheridium*.

*assimilation*. The building up of protoplasm from the materials elaborated in the plant.

*axil*. The angle or place just above the petiole of a leaf (or pedicel of a flower) where it joins the twig.

*berry*. In botany, a fleshy pericarp containing a number of seeds, as current, orange, tomato, grape, cranberry, but not strawberry, blackberry, raspberry, or mulberry.

*biennial*. A plant that lives two years. It usually blooms the second year.

*blade*. The expanded part of a leaf.

*bract*. A small or much-reduced leaf, often a mere scale.

*calyx*. The outer row or series in the floral envelope. The outer "leaves" of the flower, usually green.

*cambium*. Growth tissue, lying between the bark-part and wood-part of the fibro-vascular bundle and giving rise to the cells of both.

*capsule*. A pod consisting of two or more carpels or parts, usually opening naturally.

*carbohydrate*. The compounds of the starch and sugar class.

*carpel*. One part or member of a compound pistil, or a simple pistil itself.

*catkin or ament*. A raceme-like or spike-like flower-cluster that falls away after flowering or fruiting, as of willows and staminate flower-clusters of walnuts and birches.

*centrifugal*. From the inside out; as a flower-cluster of which the inside, terminal, or uppermost flowers open first; a determinate cluster.

*centripetal*. From the outside in; as a flower-cluster of which the outer flowers open first; an indeterminate cluster.

*chlorophyll*. Leaf green. Chlorophyll is the pigment that gives the characteristic colour to plants.

*cladophylla*. Stems that look like leaves, and function as leaves, as in asparagus and the florists' smilax.

*cleistogamous*. Applied to small flowers, usually hidden beneath the earth, that are little developed as to floral envelopes, and are self-fertilized; also to self-fertilization in flowers that do not open.

*complete flowers* have all the parts, — calyx, corolla, stamens, pistil.

*corolla*. The inner row or series of flower-leaves, usually coloured, and often of irregular shape. It may be all one piece or of many pieces.

*corymb*. A flattish flower-cluster in which the outermost flowers open first.

*cotyledon*. A leaf of the embryo; seed-leaf. The embryo may have one cotyledon (monocotyledon), or two cotyledons (dicotyledon), or sometimes more than two.

*cross-fertilization* is fertilization by means of pollen produced in another flower.

*cryptogam*. One of the group of flowerless or non-seed-bearing plants, as a fern, fungus, moss, seaweed.

*cutting*. A shoot planted in soil or water for the purpose of making a new plant.

*cyme*. A flattish or broad flower-cluster in which the innermost or terminal flowers open first.

*decumbent*. Said of branches or stems that lop or lie over on the ground.

*decurrent*. Said of a leaf that runs down on the stem, thereby not having a distinct petiole.

*dehiscence*. The mode of opening, as of a seed-pod or an anther.



*deliquescent.* Said of trees in which the leader or main trunk disappears at the tree-top, forking into several or many main branches.

*determinate.* See *centrifugal*.

*dichogamy.* The condition when stamens and pistils in the same flower mature at different times; this prevents or hinders self-pollination. See *proterandrous* and *proterogynous*.

*declinous.* Said of flowers that are imperfect, — lacking either stamens or pistils.

*dicotyledon.* Having two cotyledons or seed-leaves.

*digestion.* Change in the food materials whereby they may be transported, or used in assimilation. Starch is changed into sugar in the plant by a process of digestion.

*dimorphous.* Of two forms; as flowers that bear two kinds of stamens.

*diæcious.* Said of plants that bear stamens and pistils in flowers on different plants.

*drupe.* A fleshy pericarp or fruit, containing a relatively large stone or pit, as peach, cherry, plum.

*drupelet.* A very small drupe, particularly one comprising part of an aggregate fruit, as a drupelet of raspberry.

*embryo.* The dormant plantlet comprising part of the seed. It is enclosed within the seed-coats. Its parts are the caulicle (or stemlet), cotyledons or seed-leaves, and plumule. The food may be stored in the embryo, or around the embryo (endosperm).

*endogen.* A plant of the monocotyledon class, not enlarging in diameter by means of outside rings; as palms. All grasses and lilies and orchids and cereal grains are of this kind. Now used, if at all, to express a general mode of growth rather than a class of plants. See *exogen*.

*endosperm.* The food material that is packed around the embryo (rather than inside it) in the seed.

*entomophilous.* Said of flowers that are pollinated by insects.

*environment.* The surroundings; or the conditions in which a plant or animal lives. The environment comprises the soil, climate, and the influence of the other plants and animals with which or among which the plant or animal grows.

*epicotyl.* The internode or "joint" above the seed-leaves or cotyledons.

*epidermis.* The outermost layer or part of the cortex; the skin.

*epigeal.* Said of seeds (as common bean) in which the cotyledons or seed-leaves rise above ground in germination. See *hypogeal*.

*epiphyte.* A plant that grows on another plant, or on other objects above ground, but which does not derive much or any of its nourishment from its host; an air-plant.

- excurrent*. Said of trees (as firs and spruces) in which the main trunk or leader continues through the tree-top.
- exogen* (see *endogen*). Of the dicotyledon class, the stem enlarging by external layers or rings.
- fertilization* takes place in the flower when a pollen nucleus and an egg-cell nucleus unite in a forming ovule.
- fibro-vascular*. Bundles or strands of tissue composed of sieve tubes, mechanical fibre and vessels or ducts.
- filament*. The stalk part of a stamen.
- follicle*. A single-cavity fruit or pod opening along its inner edge.
- frond*. A leaf of a fern and related plants.
- fruit*. In botany, the ripened ovary with the attached parts. All flowering plants, therefore, produce fruits. The term is also used for the ripened reproductive bodies of flowerless plants.
- fruit-dot, sorus*. A collection or cluster of sporangia, as in ferns.
- function*. What a plant or an organ does; how it works.
- gamete*. A cell or nucleus that takes part in fertilization.
- gametophyte*. The stage of the plant (as the prothallus) that bears or produces the sex organs; sexual stage of the plant.
- gamopetalous*. Said of a corolla with the petals united.
- gamosepalous*. Said of a calyx with the sepals united.
- generation*. The entire life period of a plant.
- geotropism*. Turning toward the earth, as the action of the roots.
- glomerule*. A dense globular or oblong flower-cluster in which the upper or inner flowers open first.
- graft*. A cutting inserted in another plant for the purpose of having it grow there.
- gymnosperm* ("naked seed"). A name applied to a group of plants (pines, spruces, cedars, and the like) in which the seeds are not contained in an ovary.
- head*. A very dense globular or oblong flower-cluster in which the outer flowers open first; often applied to any dense flower-cluster.
- herb*. A plant that never becomes woody and that dies to the ground, or dies entirely, in winter.
- hilum*. The scar or spot where the seed was attached to its stalk.
- hip*. The fruit of the rose, which is a hollowed torus containing the dry fruits or "seeds."
- homologous*. Related to, or with, in origin or structure. Thus, a tendril of grape is homologous with a branch; a tendril of grape is *analogous* to a tendril of pea (similar in function), but not homologous, for one represents a branch (or flower-cluster) and the other represents a leaf.

- host*. A plant or animal on which another organism grows or feeds.
- hypha* (plural *hyphæ*). The threads of the mycelium of a fungus.
- hypocotyl*. The stem or internode below the seed-leaves.
- hypogeal*. Said of seeds (as garden pea) in which the cotyledons remain under ground in germination. See *epigeal*.
- imperfect flowers* lack either stamens or pistils.
- incomplete flowers* lack one of the parts or series, as the calyx, corolla, stamens, or pistil.
- indeterminate*. See *centripetal*.
- indusium*. The scale or lid covering a sorus, in ferns and allied plants.
- inflorescence*. Properly, the mode of flowering (page 160), but sometimes used in the sense of a flower-cluster.
- involucre*. A set or whorl of leaves or bracts beneath a flower or a cluster of flowers; sometimes looks like an outer or extra calyx.
- irregular flowers* have some members of one or more of the series unlike their fellows.
- key fruit*. See *samara*.
- labiate*. Lipped; that is, divided into parts, as the lips of a mouth. Said usually of corollas that are lobed into two parts.
- lateral*. On the side; as a flower or leaf borne on the side of a shoot rather than at its end. See *terminal*.
- leaflet*. One of the divisions or parts of a compound leaf.
- legume*. Like a follicle, but opening along both edges. In some cases, as in peanut, the pod does not actually open.
- leguminous plants* are those that bear legumes or true pods, as peas, beans, clovers, alfalfa, vetch, sweet pea, peanut, locusts, red-bud.
- lenticel*. Very small spots or corky elevations on young twigs, marking the place of former twig stomates.
- locule*. One cavity or "cell" in a pistil or anther.
- loculicidal*. Said of capsules when the carpels or compartments open between the partitions.
- mesophyll*. The parenchyma in the leaf.
- micropyle*. The place on the seed at which the pollen-tube entered when the seed was forming (when impregnation took place).
- monocotyledon*. Having one cotyledon or seed-leaf.
- monœcious*. Said of plants that bear the stamens and pistils in different flowers on the same plant.
- mycelium*. The vegetative part of a fungus, composed of threads or hyphæ.
- mycorrhiza*. A root covered with or bearing a fungus that aids the root in securing nourishment from the soil.
- naked*. Said of flowers that lack envelopes (calyx and corolla).

*nectary*. A cup, sac, or place in the flower in which nectar (or "honey") is borne.

*osmosis*. The passing or diffusion of liquids or gases through membranes.

*ovary*. The lower enlarged part of the pistil, containing the ovules or forming seeds.

*ovule*. The young or forming seed.

*palmate*. Palm-like; said of venation that arises from the base of the leaf (top of petiole), or of leaflets similarly arranged.

*panicle*. A branching raceme. The lower or outer flowers open first; but the word is often used loosely.

*pappus*. The hair, plumes, bristles, or scales on the top of a dry fruit, particularly of a fruit (or "seed") of the Compositæ or sunflower family.

*parasite*. A plant or animal that lives on a living host (as on a plant or an animal), taking its food from the host. See *saprophyte*.

*parenchyma*. The general underlying tissue, from which other tissue arises.

*pedicel*. Stem of a single flower in a cluster.

*peduncle*. A flower stem, supporting a solitary flower or a cluster of flowers.

*perennial*. A plant that lives more than two years, as most grasses, docks, alfalfa, asparagus, and all trees and shrubs.

*perfect flowers* bear both stamens and pistils.

*pericarp*. A ripened ovary, without counting attached parts.

*personate*. Masked; that is, so formed as to suggest a masked face, in labiate corollas with a large lower lip.

*petal*. One of the parts or leaves of the corolla.

*petiole*. Stem or stalk of a leaf.

*petiolule*. Stem of a leaflet.

*phenogam* (*phænogam*, *phanerogam*). A seed-bearing plant; that is, one of the seed-bearing or flowering group of plants.

*phloem*. Bark or soft bast tissue.

*photosynthesis*. The process whereby the carbon dioxide of the air is appropriated in the formation of material for plant growth.

*phyllotaxy*. Mode of arrangement of leaves or flowers on the plant or stem.

*pinnate*. Feather-like; said of leaves in which the veins strike off from a continuing midrib, or in which the leaflets are arranged in a similar order.

*pistil*. The innermost member in the flower, bearing the forming seeds.

*pistillate*. Of pistils only; a flower that contains pistils and no stamens, or a plant that bears only pistils.

- plur-annual*. A plant of a tropical or semi-tropical climate that is annual in a colder country only because it is killed by frost; as tomato, castor-bean.
- pollen*. The dust or grains contained in the anther, which, falling on the stigma, grows and fertilizes the forming ovules.
- pollination*. The transfer of pollen from the anther to the stigma. The transfer may be accomplished by wind, insects, birds, water (in the case of water plants), or by the natural falling of the pollen.
- polypetalous* ("many-petaled"). Said of a corolla with the petals not united.
- polysepalous* ("many-sepaled"). Said of a calyx with sepals not united.
- pome*. An apple-like or pear-like or quince-like fruit, with a five-carpeled or ten-carpeled "core."
- proterandrous*. Said of a flower when the anthers mature in advance of the pistils in the same flower.
- proterogynous*. Said of a flower when its pistils mature before its anthers.
- prothallus* ("first thallus"). The minute leaf-like body or organ produced by the germination of a spore, in ferns and allied plants. It bears the sex organs.
- protoplasm*. The living matter in plants. It is the living part of the cells, usually in a semi-fluid, translucent state.
- pseud-annual*. A plant that is apparently annual, but which is carried over winter by a bulb, tuber, or similar body; as potato, onion.
- pyxis*. A dry fruit or capsule in which the top comes off, like a cover to a jar.
- raceme*. A simple (unbranched) cluster in which the flowers are on short pedicels and open from the base upwards.
- raphe*. A ridge or elevation on some seeds caused by the seed-stalk and seed-coats growing together.
- ray*. The elongated corolla-limb of some members of the Compositæ family.
- receptive*. Said of a stigma when it is "ripe" or ready to receive the pollen.
- regular flowers* are those in which all the members of each series (as all the sepals, or all the petals, or all the stamens) are like each other in shape, size, and colour.
- reinforced*. See *accessory fruits*.
- respiration*. Breathing; manifest by oxygen taken in and carbon dioxide given off.
- rhizome*. A rootstock; an underground root-like stem. It has joints, usually scales representing leaves, and is often thick and fleshy.

- samara*. A key fruit, being an indehiscent (not opening) fruit provided with a wing or wings.
- saprophyte*. A plant that lives on dead or decaying material. See *parasite*.
- scape*. A flower-stem rising directly from the crown of the plant at the surface of the ground or near it. A scape may have bracts.
- self-fertilization* or *close-fertilization* is fertilization by means of pollen produced in the same flower.
- sepal*. One of the parts or leaves of the calyx.
- septicidal*. A form of dehiscence or opening along the natural partitions of the capsule.
- sessile*. Sitting; without a stem, as a leaf without petiole, or a flower without pedicel or peduncle.
- shrub*. A low woody plant that does not have a distinct trunk. When a plant normally has a trunk, it is a tree.
- silicle*. A short, more or less circular, capsule of the mustard family.
- siliqua*. A long capsule of the mustard family.
- society*. An aggregation or company of plants, comprising a more or less distinct group.
- sorus* (plural *sori*). See *fruit-dot*.
- spadix*. A spike of flowers (each flower usually minute), with a more or less fleshy axis, and usually accompanied by a spathe.
- spathe*. A corolla-like or involucre-like leaf or bract (or a pair of them) surrounding or accompanying a spadix. In the calla, the spathe is the large white flower-like part.
- spermatophyte* ("seed plant"). A seed-bearing plant; one of the flowering-plant class.
- spike*. A dense and slender flower-cluster in which the flowers open from below upwards.
- sporangium* (plural *sporangia*; *spore-case*). A body or receptacle holding spores.
- spore*. A reproductive or generative cell; in flowerless plants answering the purpose of a seed, but containing no embryo. It may not be the direct product of fertilization.
- sporophyll* ("spore leaf"). A member or part that bears spores.
- sporophyte*. The stage of the plant arising directly from the fertilized egg, and which ordinarily produces asexual spores (as the "plant" or conspicuous part of the fern or of a seed-plant).
- stamen*. The pollen-bearing organ of the flower, of which the essential part is the anther (usually borne on a stem or filament).
- staminate*. Said of a flower that has stamens and no pistils.
- stigma*. The part of the pistil (usually on a stalk or style) on



which the pollen germinates; it is sticky, rough, or hairy at maturity.

*stipel*. A stipule of a leaflet.

*stipule*. A leafy or scale-like appendage at the base of a petiole. Stipules are usually two in each case.

*stomate, stoma* (plural *stomates* or *stomata*). The openings on leaves and green parts through which gases pass; diffusion-pores or "breathing-pores."

*stone-fruit*. A drupe.

*strict*. Said of a stem that grows straight up, without breaking into branches.

*style*. The stalk between the ovary and the stigma; sometimes not present.

*syngenesious*. Said of anthers when they cohere in a ring, as in the Compositæ, the style usually being inclosed.

*tap-root*. A single or leading strong root that runs straight down into the earth.

*tendril*. A slender coiling member of a plant that enables it to climb. A tendril may represent a branch, a petiole, a leaflet, a stipule, an entire leaf.

*terminal*. At the end; as a flower borne on the end of a shoot. See *lateral*.

*thyrs*. A compound, usually elongated or pyramidal flower-cluster in which the mode of inflorescence is mixed.

*torus*. The end of the flower-stalk (usually somewhat enlarged) to which the flower-parts are attached; receptacle.

*transpiration*. Evaporation or loss of water from plants.

*umbel*. A flower-cluster opening from the outside, in which the branches or stems arise from one place, as the rays of an opened umbrella.

*umbellet*. A small umbel, comprising part of a larger or compound umbel.

*valve*. One of the integral parts into which a fruit or an anther naturally splits, or into which it is divided.

*venation*. The mode or fashion of veining, as in a leaf or petal.

*xylem*. Wood tissue.







# BEGINNERS' ZOOLOGY

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## PREFACE

In all teaching of animals and plants to beginners, the animals themselves and the plants themselves should be made the theme, rather than any amount of definitions and of mere study in books. Books will be very useful in guiding the way, in arranging the subjects systematically, and in explaining obscure points; but if the pupil does not know the animals and plants when he has completed his course in biology, he has not acquired very much that is worth the while.

Another very important consideration is to adapt the statement of any fact to the understanding of a beginner. It is easy to fall into technicalities; but the minute explanations would mean nothing to the beginner, and their use would tend to confuse the picture which it is necessary to leave in the pupil's mind. It is impossible ever to state the last thing about any proposition. All knowledge is relative. What is very elementary to one mind may be very technical and advanced to another. It is neither necessary nor desirable to safeguard statements to the beginner by such qualifications as will make them satisfactory to the critical expert in science. The teacher must understand that while accuracy is always essential, the *degree of statement* is equally important when teaching beginners.

The value of biology study lies in the work with the actual objects. It is not possible to provide specimens for every part of the work, nor is it always desirable to do so; for the beginning pupil may not be able to interest himself in the objects, and he may become immersed in details before he has arrived at any general view or reason of the subject. Great care must be exercised that the pupil is not swamped. Mere book work or memory stuffing is useless, and it may dwarf or divert the sympathies of active young minds.

The present tendency in secondary education is away from the formal technical completion of separate subjects, and toward the developing of a workable training in the activities that relate the pupil to his own life. In the natural science field, the tendency is to attach less importance to zoology and botany as such, and to lay greater stress on the processes and adaptations of life as expressed in animals and plants. Education that is not applicable, that does not put the pupil into touch with the living knowledge and the affairs of his time, may be of less educative value than the learning of a trade in a shop. We are beginning to learn that the ideals and the abilities should be developed out of the common surroundings and affairs of life rather than imposed on the pupil as a matter of abstract unrelated theory.

It is much better for the beginning pupil to acquire a real conception of a few central principles and points of view respecting common forms that will enable him to tie his knowledge together and organize it and apply it, than to familiarize himself with any number of mere facts about the lower forms of life which, at the best, he can know only indirectly and remotely. If the pupil wishes to go farther in later years, he may then take up special groups and phases.

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# BEGINNERS' ZOOLOGY

## CHAPTER I

### THE PRINCIPLES OF BIOLOGY

BIOLOGY (Greek, *bios*, life; *logos*, discourse) means the science of life. It treats of animals and plants. That branch of biology which treats of animals is called *zoology* (Gr. *zoon*, animal; *logos*, discourse). The biological science of *botany* (Gr. *botane*, plant or herb) treats of plants.

Living things are distinguished from the not living by a series of processes, or changes (feeding, growth, development, multiplication, etc.), which together constitute what is called life. These processes are called *functions*. Both plants and animals have certain parts called *organs* which have each a definite work, or function; hence animals and plants are said to be organized. For example, men and most other animals have a certain organ (the mouth) for taking in nourishment; another (the food tube), for its digestion.

Because of its *organization*, each animal or plant is said to be an *organism*. Living things constitute the *organic kingdom*. Things without life and not formed by life constitute the *inorganic*, or *mineral, kingdom*. Mark I for inorganic and O for organic after the proper words in this list: granite, sugar, lumber, gold, shellac, sand, coal, paper, glass, starch, copper, gelatine, cloth, air, potatoes, alcohol, oil, clay. Which of these things are used for food by animals? Conclusion?

**Energy in the Organic World.** — We see animals exerting energy; that is, we see them moving about and doing work. Plants are never seen acting that way; yet they need energy in order to form their tissues, grow, and raise themselves in the air.

**Source of Plant Energy.** — We notice that green plants thrive only in the light, while animal growth is largely independent of light. In fact, in the salt mines of Poland there are churches and villages below the ground, and children are born, become adults, and live all their lives below ground, without seeing the sun. (That these people are not very strong is doubtless due more to want of fresh air and other causes than to want of sunlight.)



FIG. 1.—SURFACES OF A LEAF, magnified.

*The need of plants for sunlight shows that they must obtain something from the sun. This has been found to be energy.*

This enables them to *lift*

their *stems* in growth, and *form* the various structures called *tissues* which make up their stems and leaves. It is noticed that they take in food and water from the soil through their roots. Experiments also show that green plants take in through pores (Fig. 1), on the surface of their leaves, a gas composed of carbon and oxygen, and called *carbon dioxide*. The *energy in the sunlight* enables the plant to *separate out the carbon of the carbon dioxide* and to build mineral and water and carbon

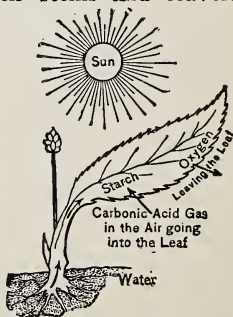


FIG. 2.—A LEAF STORING ENERGY IN SUNLIGHT.



into organic substances. The oxygen of the carbon dioxide is set free and returns to the air (Fig. 2). Starch, sugar, oil, and woody fibre are examples of substances thus formed. Can you think of any fuel not due to plants?

**How Animals obtain Energy.** — You have noticed that starch, oil, etc., will *burn*, or *oxidize*, that is, *unite with the oxygen of the air*; thus the sun's energy, stored in these substances, is changed back to heat and motion. The oxidation of oil or sugar may occur in a furnace; it may also occur in the living substance of the active animal.

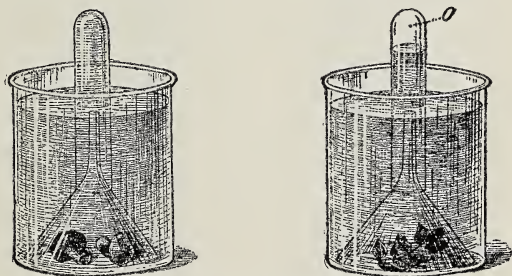


FIG. 3.—COLOURLESS plants, as MUSH-ROOMS, give off no oxygen.

A GREEN LEAF, even after it is cut, gives off oxygen (O) if kept in the sun.

Fortunately for the animals, the plants oxidize very little of the substances built up by them, since they do not move about nor need to keep themselves warm. We notice that animals are constantly using plant substances for food, and constantly drawing the air into their bodies. If the sunlight had not enabled the green plant to store up these substances and to set free the oxygen (Fig. 3), animals would have no food to eat nor air to breathe; hence we may say that the sunlight is indirectly the source of the life and energy of animals. Mushrooms and other plants without green matter cannot set oxygen free (Fig. 3).

**Experiment to show the Cause of Burning, or Oxidation.**

— Obtain a large glass bottle (a pickle jar), a short candle, and some matches. Light the candle and put it on a table near the edge, and cover it with the glass jar. The flame slowly smothers and goes out. Why is this? Is the air now in the jar different from that which was in it before the candle was lighted? Some change must have taken place or the candle would continue to burn. To try whether the candle will burn again under the jar without changing the air, slide the jar to the edge of the table and let the candle drop out. Light the candle and slip it up into the jar again, the jar being held with its mouth a little over the edge of the table to receive the candle (Fig. 5). The flame goes out at once. Evidently the air in the jar is not the same as the air outside. Take up the jar and wave it to and fro a few times, so as to remove the old air and admit fresh air. The candle now burns in it with as bright a flame as at first. So we conclude that the candle will not continue to burn unless there is a constant supply of fresh air. The gas formed by the burning is carbon dioxide. It is the gas from which plants extract carbon. (Beginners' Botany, Chap. XIII.) One test for the presence of this gas is that it forms a white, chalky cloud in lime-water; another is that it smothers a fire.

**Experiment to show that Animals give off Carbon Dioxide.**

— Place a cardboard over the mouth of a bottle containing pure air. Take a long straw, the hollow stem of a weed, a glass tube, or a sheet of stiff paper rolled into a tube, and pass the tube into the bottle through a hole in the cardboard. Without drawing in a deep breath, send one long breath into the bottle through the tube, emptying the lungs by the breath as nearly as possible (Fig. 4). Next, invert the bottle on the table as in the former experiment,

afterward withdrawing the cardboard. Move the bottle to the edge of the table and pass the lighted candle up into it (Fig. 5). Does the flame go out as quickly as in the former experiment?

If you breathe through a tube into clear lime-water, the water turns milky. The effect of the breath on the candle and on the lime-water shows that carbon dioxide is continually leaving our bodies in the breath.

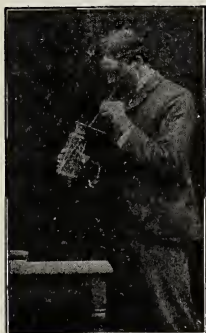


FIG. 4. — Breathing into a bottle.



FIG. 5. — Testing the air in the bottle.

**Oxidation and Deoxidation.** — The union of oxygen with carbon and other substances, which occurs in fires and in the bodies of animals, is called *oxidation*. The separation of the oxygen from carbon such as occurs in the leaves of plants is called *deoxidation*. *The first process sets energy free, the other process stores it up.* Animals give off carbon dioxide from their lungs or gills, and plants give off oxygen from their leaves. But plants need some energy in growing, so oxidation also occurs in plants, but to a far less extent than in animals. At night, because of the absence of sunlight, no deoxidation is taking place

in the plant, but oxidation and growth continue; *so at night the plant actually breathes out some carbon dioxide*. The deepest part of the lungs contains the most carbon dioxide. Why was it necessary to empty the lungs as nearly as possible in the experiment with the candle? Why would first drawing a deep breath interfere with the experiment? Why does closing the draught of a stove, thus shutting off part of the air, lessen the burning? Why does a "firefly" shine brighter at each breath? Why is the pulse and breathing faster in a fever? Very slow in a trance?

**The key for understanding any animal** is to find *how it gets food and oxygen*, and how it uses the energy thus obtained to grow, move, avoid its enemies, and get more food. Because it moves, it needs senses to guide it.

**The key for understanding a plant** is to find *how it gets food and sunlight* for its growth. It makes little provision against enemies; its food is in reach, so it needs no senses to guide it. The plant is built on the plan of having the nutritive activities *near the surface* (e.g. absorption by roots; gas exchange in leaves). The animal is built on the plan of having its nutritive activities *on the inside* (e.g. digestion; breathing).

**Cell and Protoplasm.** — Both plants and animals are composed of small parts called *cells*. Cells are usually microscopic in size. They have various shapes, as spherical, flat, cylindrical, fibre-like, star-shaped. The living substance of cells is called *protoplasm*. It is a stiff, gluey fluid, *albuminous* in its nature. Every cell has a denser spot or kernel called a *nucleus*, and in the nucleus is a still smaller speck called a *nucleolus*. Most cells are denser and tougher on the outside, and are said to have a *cell wall*, but many cells are naked, or without a wall. Hence the indispensable part of a cell is not the wall but the nucleus,

and a *cell* may be defined as a bit of *protoplasm* containing a *nucleus*. This definition includes naked cells as well as cells with walls.

**One-celled Animals.** — There are countless millions of animals and plants the existence of which was not suspected until the invention of the microscope several centuries ago. They are one-celled, and hence microscopic in size. It is believed that the large animals and plants are descended from one-celled animals and plants. In fact, each individual plant or animal begins life as a single cell, called an egg cell, and forms its organs by the subdivision of the egg cell into many cells. An egg cell is shown in Fig. 6, and the first stages in the development of an egg cell are shown in Fig. 7.

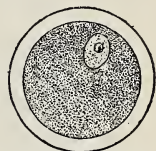


FIG. 6. — Egg cell of mammal with yolk.

The animals to be studied in the first chapter are *one-celled animals*. To understand them we must learn how



FIG. 7. — Egg cell subdivides into many cells forming a sphere (morula) containing a liquid. A dimple forms and deepens to form the next stage (gastrula).

they eat, breathe, feel, and move. They are called *Protozoans* (Greek *protos*, first, and *zoon*). All other animals are composed of many cells and are called *Metazoans* (Greek *meta*, beyond or after). The cells composing the mucous membrane in man are shown in Fig. 8. The cellular structure of the leaf of a many-celled plant is illustrated in Fig. 1.

**Method of Classifying Animals.**—The various animals display differences more or less marked. The question arises, are not some of them more closely related than others? We conclude that they are, since the difference between some animals is very slight, while the difference between others is quite marked.



FIG. 8. — MUCOUS MEMBRANE formed of one layer of cells. A few cells secrete mucus.

To show *the different steps in classifying* an animal, we will take an example,—the cow. Even little children learn to recognize a cow, although individual cows differ somewhat in form, size, colour, etc. The varieties of cows, such as short-horn, Jersey, etc., all form one *species* of animals, having the scientific name *taurus*. Let us include in a larger group the animals closest akin to a cow. We see a cat, a bison, and a dog; rejecting the cat and the dog, we see that the bison has horns, hoofs, and other similarities. We include it with the cow in a *genus* called *Bos*, calling the cow *Bos taurus*, and the bison, *Bos bison*. The sacred cow of India (*Bos indicus*) is so like the

cow and the buffalo as also to belong to the genus *Bos*. Why is not the camel, which, like *Bos bison*, has a hump, placed in the genus *Bos*?

The Old World buffaloes, — most abundant in Africa and India, — the antelopes, sheep, goats, and several other genera are placed with the genus *Bos* in a *family* called the *hollow-horned animals*.

This family, because of its even number of toes and the habit of chewing the cud, resembles the camel family,



the deer family, and several other families. These are all placed together in the next higher systematic unit called an *order*, in this case, the order of *ruminants*.

The ruminants, because they are covered with hair and nourish the young with milk, are in every essential respect related to the one-toed horses, the beasts of prey, the apes, etc. Hence they are all placed in a more inclusive division of animals, the *class* called *mammals*.

All mammals have the skeleton, or support of the body, on the inside, the axis of which is called the vertebral column. This feature also belongs to the classes of reptiles, amphibians, and fishes. It is therefore consistent to unite these classes by a general idea or conception into a great *branch* of animals called the *vertebrates*.

Returning from the general to the particular by successive steps, state the branch, class, order, family, genus, and species to which the cow belongs.

**The Eight Branches or Sub-kingdoms.**—The simplest classification divides the whole animal kingdom into eight branches, named and characterized as follows, beginning with the lowest: I. PROTOZOANS. One-celled. II. SPONGES. Many openings. III. POLYPS. Circular; cup-like; having only one opening which is both mouth and vent. IV. ECHINODERMS. Circular; rough-skinned; two openings. V. MOLLUSCS. No skeleton; usually with external shell. VI. VERMES. Elongate body, no jointed legs. VII. ARTHROPODS. External jointed skeleton; jointed legs. VIII. VERTEBRATES. Internal jointed skeleton with axis or backbone.<sup>1</sup>

<sup>1</sup> This is the briefest classification. Animals have also been divided into twelve branches. The naming of animals is somewhat chaotic at present, but an attempt to come to an agreement is now being made by zoölogists of all nations.

## CHAPTER II

### PROTOZOA (One-celled Animals)

#### THE AMŒBA

*Amoeba or  
Paramecium*

SUGGESTIONS. — Amœbas live in the slime found on submerged stems and leaves in standing water, or in the ooze at the bottom. Water plants may be crowded into a glass dish and allowed to decay, and after about two weeks the amœba may be found in the brown slime scraped from the plants. An amœba culture sometimes lasts only three days. The most abundant supply ever used by the writer was from a bottle of water where some oats were germinating. Use  $\frac{1}{5}$  or  $\frac{1}{6}$  inch objective, and cover with a thin cover glass. Teachers who object to the use of the compound microscope in a first course should require a most careful study of the figures.

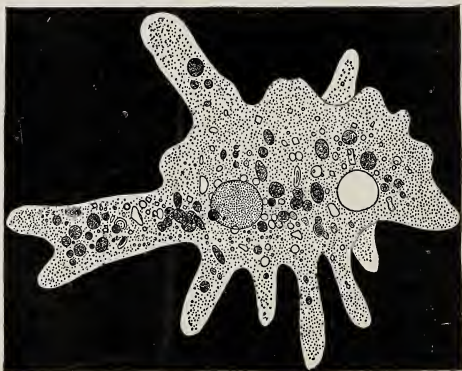


FIG. 9—AMŒBA PROTENS, much enlarged.

**Form and Structure.** — The amœba looks so much like a clear drop of jelly that a beginner cannot be certain that he has found one until it moves. It is a speck of protoplasm (Fig. 9), with a clear outer layer, the *ectoplasm*; and a granular, internal part, the *endoplasm*. Is there a distinct line between them? (Fig. 10.)

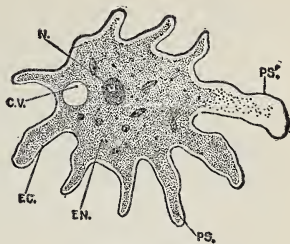


FIG. 10.—AMŒBA.

Note the central portion and the slender prolongations or *pseudopods* (Greek, false feet). Does the endoplasm extend into the pseudopods? (Fig. 10.) Are the pseudopods arranged with any regularity?

*cv*, contractile vacuule; *ec*, ectoplasm; *en*, endoplasm; *n*, nucleus; *ps*, pseudopod; *ps*, pseudopod forming; ectoplasm protrudes and endoplasm flows into it.

Sometimes it is possible to see a denser appearing portion, called the *nucleus*; also a clear space, the *contractile vacuule* (Fig. 10).

**Movements.** — Sometimes while the pseudopods are being extended and contracted, the central portion remains in the same place (this is *motion*). Usually only one pseudopod is extended, and the body flows into it; this is *locomotion* (Fig. 11). There is a new foot made for each step.



FIG. 11.—The same amœba seen at different times.

**Feeding.** — If the amœba crawls near a food particle, the *pseudopod is pressed against it*, or a depression occurs (Fig. 12), and the particle is soon embedded in the endoplasm. Often a clear space called a *food vacuole* is noticed around the food particle. This is the water that is taken in with



FIG. 12. — THE AMOEBA taking food.

the particle (Fig. 12). The water and the particle are soon absorbed and assimilated by the endoplasm.

**Excretion.** — If a particle of sand or other indigestible matter is taken in, *it is left behind* as the amoeba moves on. There is a clear space called the *contractile vacuole*, which slowly contracts and disappears, then reappears and expands (Figs. 9 and 10). This possibly aids in excreting oxidized or useless material.

**Circulation** in the amoeba consists of the movement of its protoplasmic particles. It lacks special organs of circulation.

**Feeling.** — *Jarring* the glass slide seems to be felt, for it causes the activity of the amoeba to vary. It does not take in for food every particle that it touches. This may be the beginning of *taste*, based upon mere chemical affinity. The pseudopods aid in feeling.

**Reproduction.** — Sometimes an amoeba is seen dividing into two parts. A *narrowing* takes place in the middle; the *nucleus also divides*, a part going to each portion (Fig. 13).

The mother amoeba finally divides into two daughter amoebas. Sex is wanting.

**Source of the Amoeba's Energy** — We thus see that the amoeba moves without feet, eats without a mouth, digests without a stomach, feels without nerves, and, it should also be stated, breathes without lungs, for *oxygen is absorbed from the water by its whole*



FIG. 13. — AMOEBA, Dividing.

*surface.* Its *movements require energy*; this, as in all animals, is furnished by the *uniting of oxygen with the food*. Carbon dioxide and other waste products are formed by the union; these pass off at the surface of the amœba and taint the water with impurities.

**Questions.**—Why will the amœba die in a very small quantity of water, even though the water contains enough food? Why will it die still quicker if air is excluded from contact with the drop of water?

The amœba never dies of old age. Can it be said to be immortal?

According to the definition of a cell (*Chapter I*), is the amœba a unicellular or multicellular animal?

**Cysts.**—If the water inhabited by a protozoan dries up, it encysts, that is, it forms a tough skin called a cyst. Upon return of better conditions it breaks the cyst and comes out. Encysted protozoans may be blown through the air: this explains their appearance in vessels of water containing suitable food but previously free from protozoans.

### THE SLIPPER ANIMALCULE OR PARAMECIUM

**SUGGESTIONS.**—Stagnant water often contains the paramecium as well as the amœba; or they may be found in a dish of water containing hay or finely cut clover, after the dish has been allowed to stand in the sun for several days. A white film forming on the surface is a sign of their presence. They may even be seen with the unaided eye as tiny white particles by looking through the side of the dish or jar. Use at first a  $\frac{1}{8}$  or  $\frac{1}{4}$  in. objective. Restrict their movements by placing cotton fibres beneath the cover glass; then examine with  $\frac{1}{8}$  or  $\frac{1}{6}$  objective. Otherwise, study figures.

**Shape and Structure.**—The paramecium's whole body, like the amœba's, is only one cell. It resembles a slipper in *shape*, but the pointed end is the hind end, the *front end* being rounded (Fig. 14). The paramecium is propelled by the rapid beating of numerous fine, threadlike append-

ages on its surface, called *cilia* (Latin, eyelashes) (Figs.). The cilia, like the pseudopods of the amœba, are merely prolongations of the cell protoplasm, but they are permanent. The separation between the outer *ectoplasm* and the interior granular *endoplasm* is more marked than in the amœba (Fig. 14).

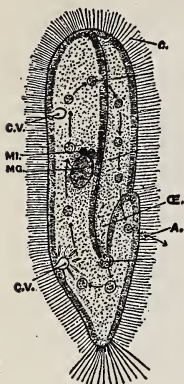


FIG. 14. — PARAMECIUM, showing cilia, *c*.

Two contractile vacuoles, *cv*; the macronucleus, *mg*; two micronuclei, *mi*; the gullet (*Æ*), a food ball forming and ten food balls in their course from gullet to vent, *a*.

**Nucleus and Vacuoles.** — There is a large nucleus called the macronucleus, and beside it a smaller one called the micronucleus. They are hard to see. About one third of the way from each end is a clear, pulsating space (*bb*. Fig. 15) called the pulsating vacuole. These spaces contract until they disappear, and then reappear, gradually ex-



FIG. 15.

panding. Tubes lead from the vacuoles which probably serve to keep the contents of the cell in circulation.

**Feeding.** — A depression, or *groove*, is seen on one side; this serves as a mouth (Figs.). A *tube* which serves as a gullet leads from the mouth-groove to the interior of the cell. The mouth-groove is lined with cilia which sweep food particles inward. The particles accumulate



FIG. 16. — TWO PARAMECIA exchanging parts of their nuclei.



in a mass at the inner end of the gullet, become separated from it as a *food ball* (Fig. 14), and sink into the soft protoplasm of the body. The food balls follow a circular course through the endoplasm, keeping near the ectoplasm.

**Reproduction.**—This, as in the amœba, is by division, the constriction being in the middle, and part of the nucleus going to each half. Sometimes two individuals come together with their mouth-grooves touching and exchange parts of their nuclei (Fig. 16). They then separate and each divides to form two new individuals.



FIG. 18.—  
Euglena.

We thus see that the paramecium, though of only one cell, is a much more complex and advanced animal than the amœba. The tiny paddles, or cilia, the mouth-groove, etc., have their special duties similar to the specialized organs of the many-celled animals to be studied later.

If time and circumstances allow a prolonged study, several additional facts may be observed by the pupil, *e.g.* Does the paramecium swim with the same end always foremost, and same side uppermost? Can it move backwards? Avoid obstacles? Change shape in a narrow passage? Does refuse



FIG. 17.—VORTICELLA (or bell animalcule), two extended, one withdrawn.

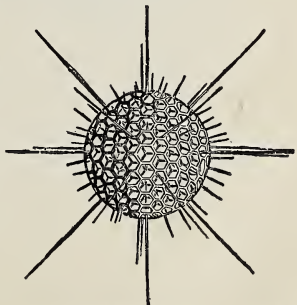


FIG. 19.—SHELL OF A RADIOLARIAN.

matter leave the body at any particular place? Trace movement of the food particles.

Draw the paramecium.

Which has more permanent parts, the *amœba* or *paramecium*? Name two anatomical similarities and three differences; four functional similarities and three differences.

The *amœba* belongs in the class of protozoans called *Rhizopoda*, "root footed."

**Other classes of Protozoans** are the *Infusorians* (in the broad sense of the term), which have many waving cilia (Fig. 17) or one whip-like flagellum (Fig. 18), and the *Foraminifers*, which possess a calcareous shell pierced with holes (Fig. 19). Much chalky limestone has been formed of their shells. To which class does the paramecium belong?

Protozoans furnish a large amount of food to the higher animals.

## CHAPTER III

### SPONGES

**SUGGESTIONS.**—In many parts of North America, fresh-water sponges may, by careful searching, be found growing on rocks and logs in clear water. They are brown, creamy, or greenish in colour, and resemble more a cushion-like plant than an animal. They have a characteristic gritty feel. They soon die after removal to an aquarium.

A number of common small bath sponges may be bought and kept for use in studying the skeleton of an ocean sponge. These sponges should not have large holes in the bottom; if so, too much of the sponge has been cut away. A piece of marine sponge preserved in alcohol or formalin may be used for showing the sponge with its flesh in place. Microscopic slides may be used for showing the spicules.

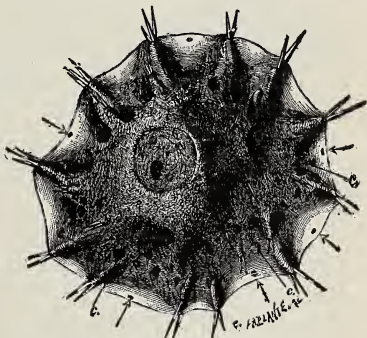


FIG. 21. — FRESH-WATER SPONGE.

The small fresh-water sponge (Fig. 21) lacks

the more or less vase-

like form typical of sponges.

It is a rounded mass growing

upon a rock or a log. As indicated by the Arrows, where does

water enter the sponge? This

may be tested by putting colour-

ing matter in the water near

the living sponge. Where does

the water come out? (Fig. 22.)

Does it pass through *ciliated*

*chambers* in its course? Is the



FIG. 22. — SECTION of fresh-water sponge (enlarged).

surface of the sponge rough or smooth? Do any of the skeletal *spicules* show on the surface? (Fig. 21.) Does the sponge thin out near its edge?

The egg of this sponge is shown in Fig. 23. It escapes from the parent sponge through the *osculum*, or large outlet. As in



FIG. 23. — EGGS AND SPICULES of fresh-water sponge (enlarged).

most sponges, the first stage after the egg is ciliated and free-swimming.

### Marine Sponges. —

The *grantia* (Fig. 24) is one of the simplest of

marine sponges. What is the *shape* of *grantia*? What is its length and diameter? How does the free end differ from the fixed end? Are the *spicules* projecting from its body few or many?

Where is the *osculum*, or large outlet? With what is this surrounded? The osculum opens from a central cavity called the *cloaca*. The canals from the pores lead to the cloaca.

*Buds* are sometimes seen growing out from the sponge near its base. These are young sponges formed asexually. Later they become detached from the parent sponge.

**Commercial "Sponge."** — What part of the complete animal remains in the bath sponge? *Slow growing sponges* grow more at the top and form tall, simple, tubular or vase-like animals. *Fast growing sponges* grow on all sides at once and form a complicated system of canals, pores, and oscula. Which of these habits of growth do you think



FIG. 25. — Plan of a sponge.



FIG. 24. — *Grantia*.

belonged to the bath sponge? Is there a large hole in the base of your specimen? If so, this is because the cloaca was reached in trimming the lower part where it was attached to a rock. Test the *elasticity* of the sponge when dry and when wet by squeezing it. Is it softer when wet or dry? Is it more elastic when wet or dry? How many *oscula* does your specimen have? How many *inhalent pores* to a square inch?

Using a probe (a wire with knob at end, or small hat pin), try to trace the *canals* from the pores to the cavities inside.

Do the *fibres* of the sponge appear to interlace, or join, according to any system? Do you see any fringe-like growths on the surface which show that new tubes are beginning to form? Was the sponge growing faster at the top, on the sides, or near the bottom?

Burn a bit of the sponge; from the odour, what would you judge of its composition? Is the inner cavity more conspicuous in a simple sponge or in a compound sponge like the bath sponge? Is the bath sponge



FIG. 26. — Bath Sponge.

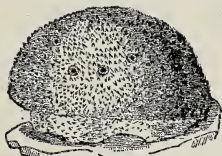


FIG. 27. — Bath Sponge.



FIG. 28. — Bath Sponge.

branched or lobed? Compare a number of specimens (Figs. 26, 27, 28) and decide whether the common sponge has a typical shape. What features do their forms possess in common?

Sponges are divided into *three classes*, according as their skeletons are flinty (silicious), limy (calcareous), or horny.

Some of the *silicious sponges* have skeletons that resemble spun glass in their delicacy. Flint is chemically nearly the same as glass. The skeleton shown in Fig. 29 is that of a glass sponge which lives near the Philippine Islands.

The *horny sponges* do not have spicules in their skeletons, as the flinty and limy sponges have, but the skeleton is composed of interweaving fibres of



FIG. 29. — Skeleton of a glass sponge.

*spongin*, a durable substance of the same chemical nature as silk (Figs. 30 and 31).

The *limy sponges* have skeletons made of numerous spicules of lime. The three-rayed spicule is the commonest form.

The commercial sponge, seen *as it grows in the ocean*, appears as a roundish mass with a smooth, dark exterior, and having about the consistency of beef liver. Several large openings (oscula), from which the water flows, are visible on the upper surface. Smaller holes (inhalant pores—many of them so small as to be indistinguishable) are on the sides. If the sponge is disturbed,

the smaller holes, and perhaps the larger ones, will close.

The outer layer of cells serves as a sort of skin. Since so much of the sponge is in contact with water, most of the cells do their own breathing, or absorp-



FIG. 30. — A horny sponge.



FIG. 31. — Section of horny sponge.

tion of oxygen and giving off of carbon dioxide. *Nutriments* is passed on from the surface cells to nourish the rest of the body.

**Reproduction.** — Egg-cells and sperm-cells are produced by certain cells along the canals. The egg-cell, after it is fertilized by the sperm-cell, begins to divide and form new cells, some of which possess cilia. The embryo sponge passes out at an osculum. By the vibration of the cilia, it swims about for a while. It afterwards settles down with the one end attached to the ocean floor and remains fixed for the rest of its life. The other end develops oscula. Some of the cilia continue to vibrate and create currents which bring food and oxygen.

The *cilia* in many species are found only in cavities called ciliated chambers. (Figs. 22, 32.) There are *no distinct organs* in the sponge and there is very little *specialization* of cells. The ciliated cells and the reproductive cells are the only specialized cells. The sponges were for a long time considered as colonies of separate one-celled animals classed as protozoans. They are,



without doubt, many-celled animals. If a living sponge is cut into pieces, each piece will grow and form a complete sponge.

**That the sponge is not a colony of one-celled animals**, each like an amoeba, but is a many-celled animal, will be realized by examining Fig. 32, which shows a bit of sponge highly magnified. A sponge may be conceived as having developed from a one-celled

animal as follows: Several one-celled animals happened to live side by side; each possessed a thread-like flagellum (E, Fig. 32) or whip-lash for striking the water. By lashing the water, they caused a stronger current (Fig. 25) than protozoans living singly could cause. Thus they obtained more food and multiplied more rapidly than those living alone. The habit of working together left its impress on the cells and was transmitted by inheritance.

Cell joined to cell formed a ring; ring

joined to ring formed a tube which was still more effective than a ring in lashing the water into a current and bringing fresh food (particles of dead plants and animals) and oxygen.

**Few animals eat sponges**; possibly because spicules, or fibres, are found throughout the flesh, or because the taste and the odour are unpleasant enough to protect them. Small animals sometimes crawl into sponges to hide. One sponge grows upon shells inhabited by hermit crabs. Moving of the shell from place to place is an advantage to the sponge, while the sponge conceals and thus protects the crab.

**Special Report: *Sponge "Fisheries."*** (Localities; how sponges are taken, cleaned, dried, shipped, and sold.)

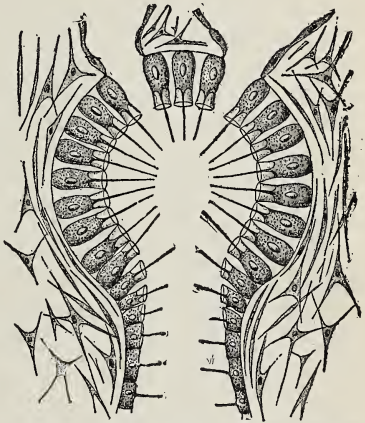


FIG. 32. — Microscopic plan of ciliated chamber. Each cell lining the chamber has a nucleus, a whip-lash, and a collar around base of whip-lash. *Question*: State two uses of whip-lash.

## CHAPTER IV

### POLYPS (CUPLIKE ANIMALS)

#### THE HYDRA, OR FRESH-WATER POLYP

SUGGESTIONS.—Except in the drier regions of North America the hydra can usually be found by careful search in fresh-water ponds not too stagnant. It is found attached to stones, sticks, or leaves, and has a slender, cylindrical body from a quarter to half an



FIG. 33.—  
A HYDRA.

inch long, varying in thickness from that of a fine needle to that of a common pin. The green hydra and the brown hydra, both very small, are common species, though hydras are often white or colourless. They should be kept in a large glass dish filled with water. They may be distinguished by the naked eye but are not studied satisfactorily without a

magnifying glass or microscope. Place a living specimen attached to a bit of wood in a watch crystal filled with water, or on a hollowed slip, or on a slip with a bit of weed to support the cover glass, and examine with hand lens or lowest power of microscope. Prepared microscopical sections, both transverse and longitudinal, may be bought of dealers in microscopic supplies. One is shown in Fig. 39.

Is the hydra's body round or two-sided? (Fig. 35.) What is

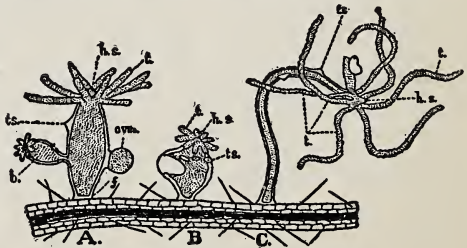


FIG. 34.—Forms assumed by Hydra.

Does one individual keep the same shape? (Fig. 34.) How does the length of the thread-

like *tentacles* compare with the length of the hydra's body? About how many tentacles are on a hydra's body? Do all have the same number of tentacles? Are the tentacles knotty or smooth? (Fig. 35.) The hydra is usually extended and slender; sometimes it is contracted and rounded. In which of these conditions is the base (the foot) larger around than the rest of the body? (Fig. 34.) Smaller? How many *openings* into the body are visible? Is there a depression or an eminence at the base of the tentacles? For what is the *opening* on top of the body probably used? Why are the tentacles placed at the top of the hydra's body? Does the *mouth* have the most convenient location possible?

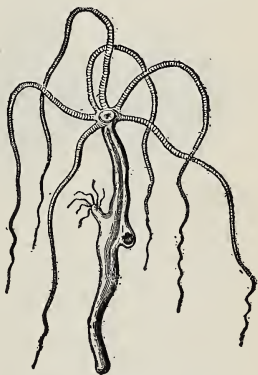


FIG. 35. — HYDRA (much enlarged).

The conical projection bearing the *mouth* is called *hypostome* (Fig. 34). The mouth opens into the *digestive cavity*. Is this the same as the general body cavity, or does the stomach have a wall distinct from the *body cavity*? How far down does the body cavity extend? Does it extend up into the tentacles? (Fig. 39.)

If a *tentacle is touched*, what happens? Is the body ever bent? Which is more sensitive, the columnar body or the tentacles? In searching for hydras would you be more likely to find the tentacles extended or drawn in? Is the hypostome ever extended or drawn in? (Fig. 34.)

**Locomotion.** — The round surface, or disk, by which the hydra is attached, is called its foot. Can you move on one foot without hopping? The hydra moves by alter-

nately elongating and rounding the foot. Can you discover other ways by which it moves? Does the hydra always stand upon its foot?

**Lasso Cells.** — Upon the tentacles (Fig. 35) are numerous cells provided each with a thread-like process (Fig. 36)



FIG. 36. — NETTLING CELL.  
II. discharged, and I. not discharged.

which lies coiled within the cell, but which may be thrown out upon a water flea, or other minute animal that comes in reach. The touch of the lasso paralyzes the prey (Fig. 37). These cells are variously called lasso cells, netting cells, or thread cells. The thread is

hollow and is pushed out by the pressure of liquid within. When the pressure is withdrawn the thread goes back as the finger of a glove may be turned back into the glove by turning the finger outside in.

When a minute animal, or other particle of food comes in contact with a tentacle, how does the tentacle get the food to the mouth? By bending and bringing the end to the mouth, or by shortening and changing its form, or in both ways? (Fig. 34, C.) Do the neighbouring tentacles seem to bend over to assist a tentacle in securing prey? (Fig. 34, C.)

**Digestion.** — The food particles break up before remaining

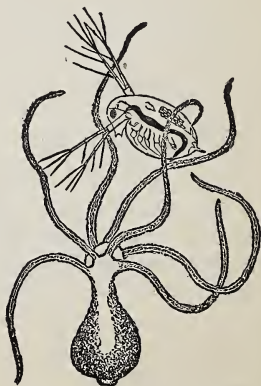


FIG. 37. — HYDRA capturing a water flea.

long in the stomach, and the nutritive part is absorbed by the lining cells, or endoderm (Fig. 39). The indigestible remnants go out through the mouth. The hydra is not provided with a special vent. Why could the vent not be situated at the end opposite the mouth?

**Circulation and Respiration.** — Does water have free access to the body cavity? Does the hydra have few or nearly all of its cells exposed to the water in which it lives? From its structure, decide whether it can breathe like a sponge or whether special respiratory cells are necessary to supply it with oxygen and give off carbon dioxide. Blood vessels are unnecessary for transferring oxygen and food from cell to cell.



FIG. 38. — HYDRAS on the under surface of pondweed.

**Reproduction.** — Do you see any swellings upon the side of the hydra? (Fig. 34, A.) If the swelling is near the tentacles, it is a *spermary*; if near the base, it is an *ovary*. A sperm coalesces with or fertilizes the ovum after the ovum is exposed by the breaking of the ovary wall. Sometimes the sperm from one hydra unites with the ovum of another hydra. This is called *cross-fertilization*. The same term is applied to the process in plants when the male element, developed in the pollen of the flower, unites with the female element of the ovule of the flower on another plant. The hydra, like most plants and some other animals, is *hermaphrodite*, that is to say, both sperms and ova are produced by one individual. In the autumn, eggs are produced with hard shells to withstand the cold until spring. Sexual reproduction takes place when food is

scarce. Asexual generation (by budding) is common with the hydra when food supply is abundant. After the bud

grows to a certain size, the outer layer of cells at the base of the bud constricts and the young hydra is detached.

Compare the sponge and the hydra in the following respects: — many celled, or one celled; obtaining food; breathing; tubes and cavities; openings; reproduction; locomotion. Which ranks higher

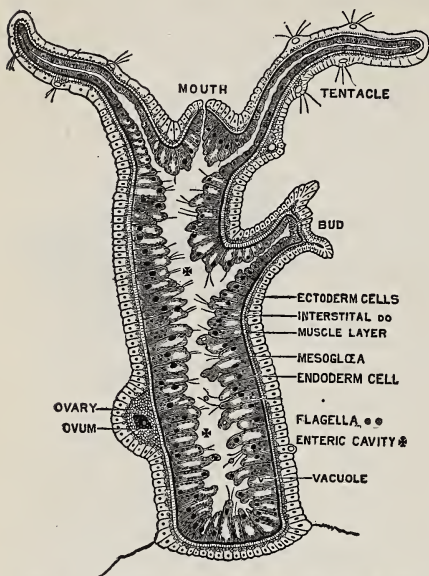


FIG. 39. — Longitudinal section of hydra (microscopic and diagrammatic).

among the metazoa? The metazoa, or many-celled animals, include all animals except which branch?

Figure 39 is a *microscopic view* of a vertical section of a hydra to show the **structure of the body wall**. There is an outer layer called the *ectoderm*, and an inner layer called the *endoderm*. There is also a thin supporting layer (black in the figure) called the *mesoglea*. The mesoglea is the thinnest layer. Are the cells larger in the endoderm or the ectoderm? Do both layers of cells assist in forming the reproductive bud? The ectoderm cells end on the inside in contractile tails which form a thin line and have the effect of muscle fibres. They serve the hydra for its remarkable changes of shape. When the hydra is cut in pieces, each piece makes a complete hydra, provided it contains both endoderm and ectoderm.



In what ways does the hydra show "division of labour"? Answer this by explaining the classes of cells specialized to serve a different purpose. Which cells of the hydra are least specialized? In what particulars is the plan of the hydra different from that of a simple sponge? An ingenious naturalist living more than a century ago, asserted that it made no difference to the hydra whether the ectoderm or the endoderm layer were outside or inside, — that it could digest equally well with either layer. He allowed a hydra to swallow a worm attached to a thread, and then by gently pulling in the thread, turned the hydra inside out. More recently a Japanese naturalist showed that the hydra could easily be turned inside out, but he also found that when left to itself it soon reversed matters and returned to its natural condition, that the cells are really specialized, and each layer can do its own work and no other.

**Habits.** — The hydra's whole body is a hollow bag, the cavity extending even into the tentacles. The tentacles may increase in number as the hydra grows, but seldom exceed eight. The hydra has more active motion than locomotion. It seldom moves from its place, but its tentacles are constantly bending, straightening, contracting, and expanding. The body is also usually in motion, bending from one side to another. When the tentacles approach the mouth with captured prey, the mouth (invisible without a hand lens) opens widely, showing five lobes or lips, and the booty is soon tucked within. A hydra can swallow an animal larger in diameter than itself.

The **endoderm cells** have *amœboid motion*, that is, they extend pseudopods. They also resemble amœbas in the power of *intra-cellular digestion*; that is, they absorb the harder particles of food and digest them afterwards, rejecting the indigestible portions. Some of these cells have *flagella* (see Fig. 39) which keep the fluid of the cavity in constant motion.

Sometimes the **hydra moves** after the manner of a small caterpillar called a "measuring worm," that is, it takes hold first by the foot, then by the tentacles, looping its

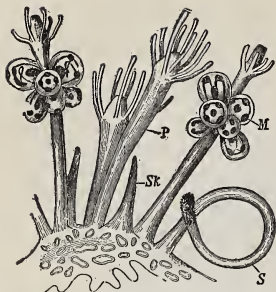


FIG. 40. — HYDROID COLONY, with nutritive (*P*) reproductive (*M*) and defensive (*S*) hydranths.

body at each step. Sometimes the body goes end over end in slow somersaults.

The *length* of the extended hydra may reach' one half inch. When touched, both tentacles and body contract until it looks to the unaided eye like a round speck of jelly. This shows *sensibility*, and a few small star-shaped cells are believed to be *nerve*

*cells*, but the hydra has not a nervous *system*. Hydras show their liking for light by moving to the side of the vessel or aquarium whence the light comes.

**The Branch Polyps** (sometimes called *Cælen-terata*). The hydra is the chief *fresh-water rep-resentative* of this great branch of the animal kingdom. This branch is characterized by its members having only one opening to the body. The polyps also include the salt water animals called *hydroids*, *jelly-fishes*, and *coral polyps*.

**Hydroids.** — Figure 40 shows a *hydroid*, or group of hydra-like growths, one of which

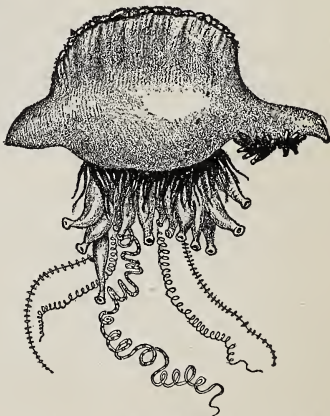


FIG. 41. — "PORTUGUESE MAN-O'-WAR" (compare with Fig. 40). A floating hydroid colony with long, stinging (and sensory) streamers. Troublesome to bathers in Gulf of Mexico. Notice balloon-like float.

eats and digests for the group, another defends by nettling cells, another produces eggs. Each hydra-like part of a hydroid is called a *hydranth*. Sometimes the buds on the hydra remain attached so long that a bud forms upon the first bud. Thus three generations are represented in one organism. Such growths show us that it is not always easy to tell what constitutes an individual animal.

*Hydroids* may be conceived to have been developed by the failure of budding hydras to separate from the parent, and by

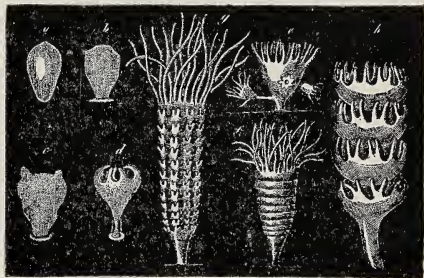


FIG. 42. — The formation of many free swimming jelly-fishes from one fixed hydra-like form. The saucer-like parts (*b*) turn over after they separate and become like Fig. 43 or 44. Letters show sequence of diagrams.

the gradual formation of the habit of living together and assisting one another. When each hydranth of the hydroid devoted itself to a special function of digestion, defence, or reproduction, this group lived longer and prospered; more eggs were formed, and the habits of the group were transmitted to a more numerous progeny than were the habits of a group where members worked more independently of one another.

As the *sponge* is a simple example of the devotion of *special cells to special purposes*, the hydroid is a primitive and simple example of the occurrence of *organs*, that is of *special parts of the body set aside for a special work*.

How many mature hydranths are seen in the hydroid shown in Fig. 40? Why are the defensive hydranths

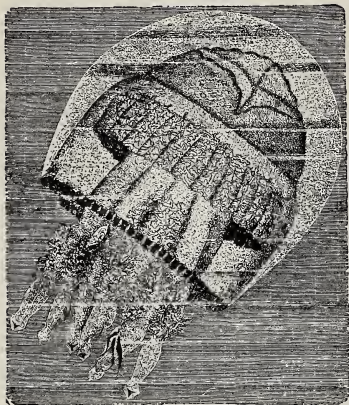


FIG. 43. — A JELLYFISH.

on the outside of the colony? Which hydranths have no tentacles? Why not?

**Jellyfish.** — **Alternation of Generations.** — **Medusa.** — With some species of hydroids, a very curious thing happens. — The *hydranth* that is to produce the eggs falls off and becomes independent of the colony. More surprising still, its appear-

ance changes entirely and instead of being hydra-like, it becomes the large and complex creature called *jellyfish* (Fig. 43). But the *egg of the jellyfish* produces a small *hydra-like animal* which gives rise by budding to a *hydroid*, and the cycle is complete.

The bud (or reproductive hydranth) of the hydroid

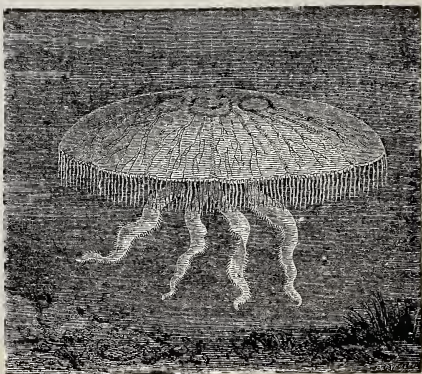


FIG. 44. — A JELLYFISH (medusa).

does not produce a hydroid, but a jellyfish; the egg of the jellyfish does not produce a jellyfish, but a hydroid. This is called by zoologists, *alternation of generations*. A *complete individual* is the life from the germination of one egg to the production of another. So that an "individual" consists of a hydroid colony fixed in one place together with all the jellyfish produced from its buds, which may now be floating miles away from it in the ocean. Bathers in the surf are sometimes touched and stung by the long, streamer-like tentacles of the jellyfish. These, like the tentacles of the hydra, have nettling cells (Fig. 41).

The umbrella-shaped free swimming jellyfish is called a *medusa* (Fig. 44).

**Coral Polyps.**—Some of the salt water relatives of the hydra produce buds which remain attached to the parent without, however, becoming different from the parent in any way.

The *coral polyps* and *corallines* are examples of *colonies* of this kind, possessing a common stalk which is formed as the process of multiplication goes on. In the case of coral polyps, the separate animals and the flesh connecting them secrete within themselves a hard, *limy, supporting structure known as coral*. In some species, the coral, or stony part, is so developed that the polyp seems to be inserted in the coral, into which it withdraws itself for partial protection (Fig. 45).

The *corallines* secrete a smooth stalk which affords no protection, but they also secrete a coating or sheath which incloses both themselves and the stalk. The



FIG. 45.—CORAL POLYPS (tentacles, a multiple of six). Notice hypostome.



coating has apertures through which the polyps protrude in order to feed when no danger is near (Fig. 46).



FIG. 46. — RED CORAL-LINE with crust and polyps (*eight* tentacles).

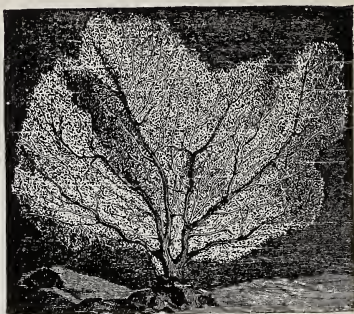


FIG. 47. — SEA FAN (a coralline).

The red “corals” used for jewelry are bits of stalks of corallines. The corallines (Figs. 47, 48) are not so abundant nor so important as the coral polyps (Figs. 45, 49).

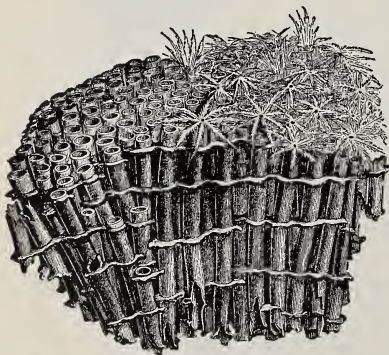


FIG. 48. — ORGAN PIPE “Coral” (a coralline).

Colonies of coral polyps grow in countless numbers in the tropical seas. The coral formed by successive colonies of polyps accumulates and builds up many islands and important additions

to continents. The Florida “keys,” or islands, and the southern part of the mainland of Florida were so formed.



The Sea Anemone, like the coral polyp, lives in the sea, but like the fresh-water hydra, it *deposits no limy support for its body*. The anemone is much larger than the

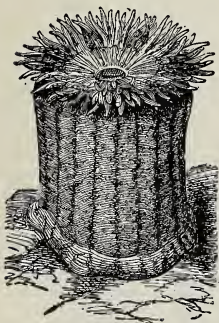


FIG. 50. — SEA ANEMONE.

hydra and most coral polyps, many species attaining a height of several inches. It *does not form colonies*.

When its arms are drawn in, it looks like a large knob of shiny but opaque jelly. Polyps used to be called *zoophytes* (*plant-animals*), because of their flower-like appearance (Figs. 50, 51).

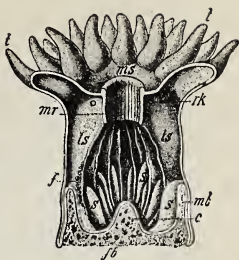
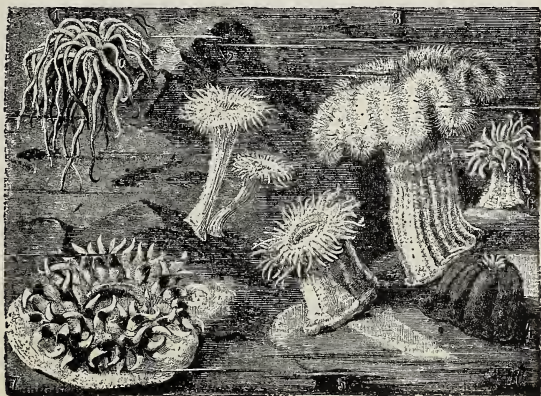


FIG. 49. — UPRIGHT CUT through coral polyp  $\times 4$

*ms*, mouth; *mr*, gullet; *ls*, fleshy partitions (mesenteries) extending from outer body wall to gullet (to increase absorbing surface); *s*, shorter partitions; *mb*, *fb*, stony support (of lime, called coral); *t*, tentacles.



## CHAPTER V

### ECHINODERMS (SPINY ANIMALS)

#### THE STARFISH

**SUGGESTIONS.** Since the echinoderms are aberrant though interesting forms not in the regular line of development of animals, this

chapter may be omitted if it is desired to shorten the course. — The common starfish occurs along the Atlantic coast. It is captured by wading along the shore when the tide is out.

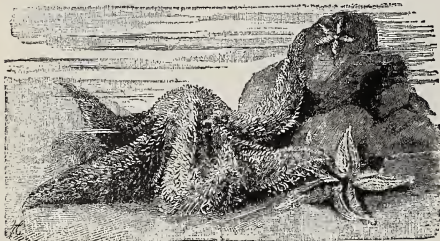


FIG. 52. — Starfish on a rocky shore.

It is killed by immersion in warm, fresh water. Specimens are usually preserved in 4 per cent. formalin. Dried starfish and sea-urchins are also useful. A living starfish kept in a pail of salt water will be instructive.

**External Features.** — Starfish are usually brown or yellow. Why? (See Fig. 52.) Has it a head or a tail? Right and left sides? What is the shape of the *disk*, or part which bears

the five arms or *rays*? (Fig. 53.) Does the body as a whole have symmetry on two sides of a line (bilateral symmetry), or around a point (radial symmetry)? Do the separate rays have

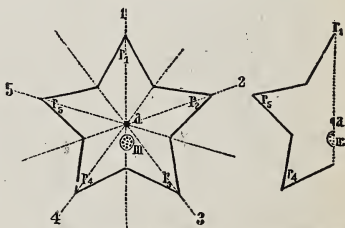


FIG. 53. — PLAN of starfish; III, madreporite.

bilateral symmetry? The *skeleton* consists of limy plates embedded in the tough skin (Fig. 54). Is the *skin* rough or smooth? Hard or soft? Are the projections (or *spines*) in the skin long or short? The skin is

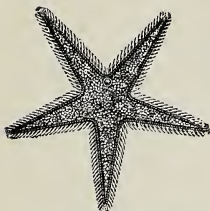


FIG. 55. — Starfish (showing MADREPORITE).

hardened by the limy plates, except around the *mouth*, which is at the centre of the lower side and surrounded by a mem-



FIG. 54. — LIMY PLATES in portion of a ray.

brane. Which is rougher, the mouth side, (*oral* side) or the opposite (*aboral* side)? Which side is more nearly flat? The *vent* is at or near the centre of the disk on the aboral surface. It is usually

very small and sometimes absent. Why a vent is not of much use will be understood after learning how the starfish takes food. An organ peculiar to animals of this branch, and called the *madreporic plate*, or *madreporite*, is found on the aboral surface between the bases of two rays (Fig. 55). It is wartlike, and usually white or red. This plate is a *sieve*; the small openings keep out sand but allow water to filter through.

#### Movements: the Water-tube System.

—The water, which is filtered through the perforated madreporite, is needed to supply a *system of canals* (Fig. 56). The madreporite opens into a canal called the *stone canal*, the wall of which is hardened by the same kind of material as that found in the skin. The stone canal leads to the *ring canal* which surrounds the mouth (Fig. 56). The ring canal sends *radial canals* into each ray to supply the double row of *tube feet* found in the groove at the lower side of each ray (Fig. 57). Because of their arrangement in rows, the feet are

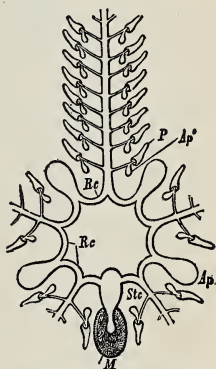


FIG. 56. — WATER tube SYSTEM of starfish.

*m*, madreporite; *stc*, stone canal; *ap*, ampulla.

also called *ambulacral* feet (Latin *ambulacra*, "forest walks"). There is a water holder (*ampulla*), or muscular water bulb at the

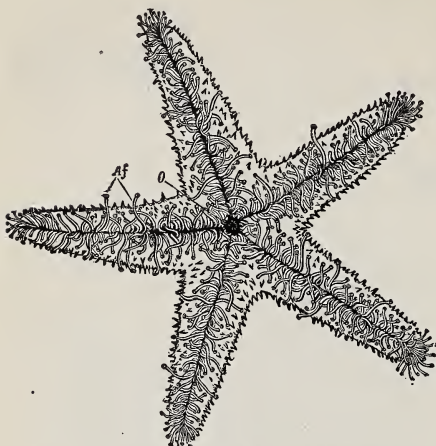


FIG. 57. — Starfish, from below; tube feet extended.

base of each tube foot (Fig. 58). These contract and force the water into the tube feet and extend them. The cuplike ends of the tubes cling to the ground by suction. The feet contain delicate muscles by which they contract and shorten. Thus the animal pulls itself slowly

along, hundreds of feet acting together. The tube feet, for their own protection, may contract and retire into the groove, the water which extended them being sent back into the ampulla.

This system of water vessels (or water-vascular system) of the echinodermata is characteristic of them; *i.e.* is not found elsewhere in the animal kingdom. The grooves and the plates on each side of them occupy the *ambulacral* areas. The rows of spines on each side of the grooves are freely movable. (What advantage?) The spines on the aboral surface are not freely movable.

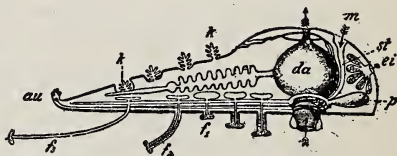


FIG. 58. — SECTION OF ONE RAY and central portion of starfish.

$f_1, f_2, f_3$ , tube feet more or less extended; *au*, eye-spot; *k*, gills; *da*, stomach; *m*, madreporite; *st*, stone canal; *p*, ampulla; *ei*, ovary.

**Respiration.**—The *system of water vessels serves the additional purpose* of bringing water containing oxygen into contact with various parts of the body, and the starfish was formerly thought to have no special respiratory organs. However, there are holes in the aboral wall through which the folds of the delicate lining membrane protrude. These are now supposed to be *gills* (*k*, Fig. 58).

The nervous system is so close to the aboral surface that much of it is visible without dissection. Its chief parts are a *nerve ring* around the mouth, which sends off a *branch* along each ray. These branches may be seen by separating the rows of tube feet. They end in a pigmented cell at the end of each ray called the *eye-spot*.

The food of starfish consists of such animals as crabs, snails, and oysters. When the prey is too large to be taken into the mouth, the starfish *turns its stomach inside out* over the prey (Fig. 59). After the shells separate, the stomach is applied to the soft digestible parts. After the animal is eaten, the stomach is retracted. This odd way of eating is very economical to its digestive powers, for *only that part of the food which can be digested and absorbed is taken into the body*. Only the lower part of the stomach is wide and extensible. The upper portion (next to the aboral surface) is not so wide. This portion receives the secretion from five pairs of digestive glands, a pair of which is situated in each ray. Jaws and teeth are absent. (Why?) The vent is sometimes wanting. Why?



FIG. 59. — Starfish eating a sea snail.  
*b*, stomach everted.

**Reproduction.**—There is a pair of ovaries at the base of each ray of the female starfish (Fig. 58). The spermaries of the male have the same position and form as the ovaries, but they are of a lighter colour, usually white.<sup>1</sup>

**Regeneration after Mutilation.**—If a starfish loses one or more rays, they are replaced by growth. Only a very ignorant oyster-man, angry at the depredations of starfish upon his oyster beds,

<sup>1</sup> The sperm-cells and egg-cells are poured out into the water by the adults, and the sperm-cell, which, like nearly all sperm-cells, has a vibratory, tail-like flagellum to propel it, reaches and fertilizes the egg-cell.



would chop starfish to pieces, as this only serves to multiply them. This power simulates multiplication by division in the simplest animals.

**Steps in Advance of Lower Branches.** — The starfish and other echinodermata have a more developed nervous system, sensory organs, and digestion, than forms previously studied; most distinctive of all, they have a body cavity distinct from the food cavity. The digestive glands, reproductive glands, and the fluid which serves imperfectly for blood, are in the body cavity. There is no heart or blood vessels. The motions of the stomach and the bending of the rays give motion to this fluid in the body cavity. It cannot be called blood, but it contains white blood corpuscles.

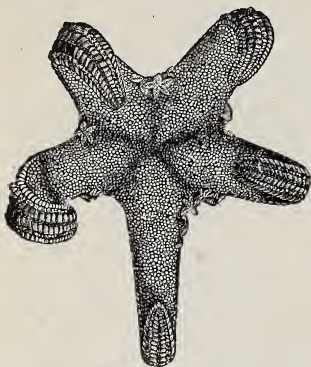


FIG. 60. — Young starfish crawling upon their mother. (Challenger Reports.)

The starfish when first hatched is an actively swimming bilateral animal, but it soon becomes starlike (Fig. 60). The limy plates of the starfish belong neither to the outer nor to the inner layer (endoderm and ectoderm) of the body wall, but to a third or middle layer (mesoderm); for echinoderms, like the polyps, belong to the three-layered animals. In this its skeleton differs from the shell of a crawfish, which is formed by the hardening of the skin itself.

**Protective Coloration.** — Many starfish are brown or yellow. This makes them inconspicuous on the brown rocks or yellow sand. Brightly coloured species are usually chosen for aquaria.

### THE SEA-URCHIN

**External Features.** — What is the *shape* of the body? What kind of *symmetry* has it? Do you find the oral (or mouth) surface? The aboral surface? Where is the body flattened? What is the shape of the spines? What is their use? How are the tube



feet arranged? Where do the rows begin and end? Would you think that a sea-urchin placed upside down in water, could right itself less or more readily than a starfish? What advantage in turning would each have that the other would not have? The name sea-urchin has no reference to a mischievous boy, but means sea-hedgehog (French *oursin*, hedgehog), the name being suggested by its spines.

**Comparison of Starfish and Sea-urchin.** — The water system of the sea-urchin, consisting of madreporite, tubes, and water bulbs, or ampullæ, is similar to that of the starfish.

The tube feet and locomotion are alike. There is no need for well-developed respiratory organs in either animal, as the whole body, inside and out, is bathed in water. The method of reproduction is the same.

The starfish eats soft animal food. The food of the sea-urchin is mainly vegetable, and it needs teeth (Fig. 62, 63);

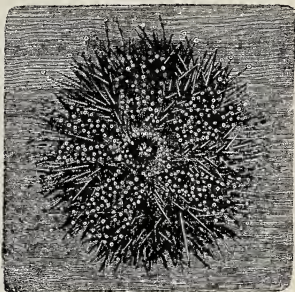


FIG. 61. — A SEA-URCHIN crawling up the glass front wall of an aquarium (showing mouth spines and tube feet).



FIG. 62. — A SEA-URCHIN with spines removed, the limy plates showing the knobs on which the spines grew.

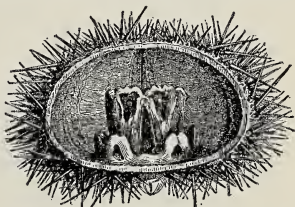


FIG. 63. — SECTION OF SEA-URCHIN with soft parts removed, showing the jaws which bear the teeth protruding in Fig. 62.

its food tube is longer than that of a starfish, just as the food tube of a sheep, whose food digests slowly, is much longer than that of a dog.

The largest species of sea-urchins are almost as big as a child's head, but such size is unusual. The spines are mounted on knobs, and the joint resembles a ball-and-socket joint, and allows a wide range of movement. Some sea-urchins live on sandy shores, other species live upon the rocks. The sand dollars are of a lighter colour. (Why)? They are usually flatter and have lighter, thinner walls than the other species. The five-holed sand cake or sand dollar has its weight still further diminished by the holes, which also allow it to rise more easily through the water.

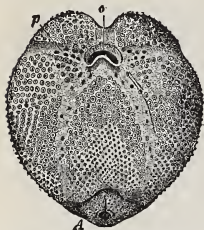


FIG. 64.—THE SEA OTTER, an urchin with mouth (*o*) and vent (*A*) on same side of body.

Both starfish and sea-urchin rest on the flattened lower surface of the body, while the tube feet are stretching forward for another step.

### OTHER ECHINODERMS

The sea-cucumbers, or holothurians, resemble the sea-urchin in many respects,

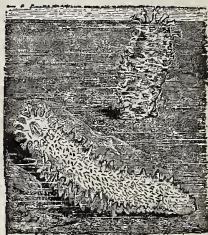


FIG. 65.—SEA-CUCUMBERS

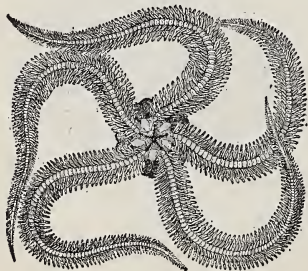


FIG. 66.—A BRITTLE STAR.

but their bodies are elongated, and the limy plates are absent or very minute. The mouth is surrounded by tentacles (Fig. 65).

The brittle stars resemble the starfish in form, but their rays are very slender, more distinct

from the disk, and the tube feet are on the edges of the rays, not under them (Fig. 66).



FIG. 67. —  
CRINOID,  
arms closed.

The **crinoids** are the most ancient of the echinoderms. (Figs. 67, 68.) Their fossils are very abundant in the rocks. They inhabited the geological seas, and it is believed that some of the other echinoderms descended from them. A few now inhabit the deep seas. Some species are fixed by stems when young, and later break away and become free-swimming, others remain fixed throughout life.



FIG. 68. — DISK OF CRINOID from above, showing mouth in centre and vent near it, at right (arms removed).

The four classes of the branch echinoderms are Starfish (*asteroids*), Sea-urchins (*echinoids*), Sea cucumbers (*holothurians*), and Sea-lilies (*crinoids*).

### Comparative Review

Make a table like this as large as the page of the notebook will allow, and fill in without guessing.

	Amœba	SPONGE	HYDRA	CORAL POLYP	STARFISH
Is body round, two-sided, or irregular					
What organs of sense					
Openings into body					
Hard or supporting parts of body					
How food is taken					
How move					
How breathe					

## CHAPTER VI

### WORMS

**SUGGESTIONS :** — Earthworms may be found in the daytime after a heavy rain, or by digging or turning over planks, logs, etc., in damp places. They may be found on the surface at night by searching with a lantern. Live specimens may be kept in the laboratory in a box packed with damp (not wet) loam and dead leaves. They may be fed on bits of fat meat, cabbage, onion, etc., dropped on the surface. When studying live worms, they should be allowed to crawl on damp paper or wood. An earthworm placed in a glass tube with rich, damp soil, may be watched from day to day.

**External Features.** — Is the body *bilateral*? Is there a *dorsal* and a *ventral* surface? Can you show this by a test with live worm? Do you know of an animal with dorsal and ventral surface, but not bilateral?



FIG. 69. — AN EARTHWORM.

Can you make out a head? A head end? A neck? Touch the head and test whether it can be made to crawl backwards. Which end is more tapering? Is the mouth at the tip of the head end or on the upper or lower surface? How is the *vent* situated? Its shape? As the worm lies on a horizontal surface, is the body anywhere flattened? Are there any very distinct divisions in the body? Do you see any *eyes*?

**Experiment** to find whether the worm is sensitive (1) to *touch*, (2) to *light*, (3) to strong *odours*, (4) to irritating liquids. Does it show a sense of *taste*? The experiments should show whether

it avoids or seeks a bright light, as of a window; also whether any parts of the body are especially sensitive to touch, or all equally sensitive. What effect when a bright light is brought suddenly near it at night?

Is *red blood* visible through the skin? Can you notice any *pulsations* in a vessel along the back? Do all earthworms have the same number of *divisions* or rings? Compare the size of the rings or segments. Can it crawl faster on glass or on paper?

A magnifying glass will show on most species tiny bristle-like projections called *setæ*. How are the setæ arranged? (*d*, Fig. 70.) How many on one ring of the worm? How do they point? Does the worm feel smoother when it is pulled forward or backward between



FIG. 70.—MOUTH AND SETÆ.



FIG. 71.—  
EARTH-  
WORM,  
mouth end  
above.

the fingers? Why? Are setæ on the lower surface? Upper surface? The sides? What is the use of the setæ? Are they useful below ground? Does the worm move at a uniform rate? What change in form occurs as the front part of the body is pushed forward? As the hinder part is pulled onward? How far does it go at each movement? At certain seasons a broad band, or ring, appears, covering several segments and making them seem enlarged (Fig. 71). This is the *clitellum*, or *reproductive girdle*. Is this girdle nearer the mouth or the tail?

**Draw the exterior of an earthworm.**

**Dorsal and Ventral Surfaces.**—The earthworm always crawls with the same surface to the ground; this is called the *ventral* surface, the opposite surface is the *dorsal* surface. This is the first animal studied to which



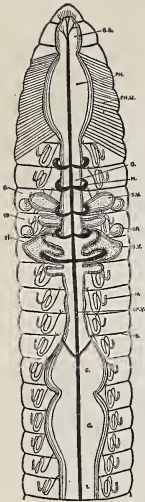


FIG. 72.—FOOD TUBE of earthworm. (Top view.)

these terms are applicable. What are the ventral and dorsal surfaces of a fish, a frog, a bird, a horse, a man?

The name “worm” is often carelessly applied to various crawling things in general. It is properly applied, however, only to *segmented animals without jointed appendages*.

Although a caterpillar crawls, it is not a worm for several reasons. It has six jointed legs, and it is not a developed animal, but only an early stage in the life of a moth or a butterfly. A “grubworm” also has jointed legs (Fig. 167). It does not remain a grub, but in the adult stage is a beetle. A worm never develops into another animal in the latter part of its life; its setæ are not jointed.

**The Food Tube.**—The earthworm has no teeth, and the food tube, as might be inferred from the form of the body, is simple and straight. Its parts, recognizable because of slight differences in size and structure, are named the pharynx (muscular), gullet, crop, gizzard (muscular), and stomach-intestine. The last extends through three fourths of the length of the body (Fig. 72). The functions of the parts of the food tube are indicated by their names.



FIG. 74.

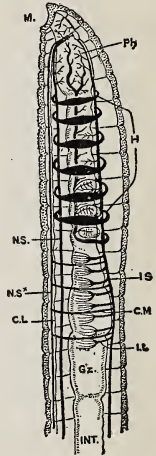


FIG. 73.—FOOD TUBE AND BLOOD VESSELS of earthworm showing the ring-like hearts. (Side view.)

**Circulation.**—There is a *large dorsal blood vessel* above the food tube (Fig. 73). From the



front portion of this tube arise several large tubular rings or "hearts" which are contractile and serve to keep the blood circulating. They lead to a *ventral vessel* below the food tube (Fig. 74). The blood is red, but the *colouring matter* is in the liquid, not in the blood cells.

**Nervous System.**—Between the ventral blood-vessels is a *nerve cord* composed of two strands (see Fig. 75). There is a slight swelling, or *ganglion*, on each strand, in each segment (Fig. 75). The strands separate near the front end of the worm, and a branch goes up each side of the gullet and enters the two pear-shaped *cerebral ganglia*, or "brain" (Fig. 75).

**Food.**—The earthworm eats earth containing organic matter, the inorganic part passing through the vent in the form of circular casts; these are found in the morning at the top of the earthworm's burrow.

The earthworm has no teeth. It excretes through the mouth an *alkaline fluid* which softens and partly digests the food before it is eaten. When this fluid is poured out upon a green leaf, the leaf at once turns brown. The starch in the leaf is also acted upon. The snout aids in pushing the food into the mouth.

**Kidneys.**—Since oxidation is occurring in its tissues, and impurities are forming, there must be some way of *removing impurities from the tissues*. The earthworm does not possess one-pair organs like the kidneys of higher animals to serve this purpose, but it has numerous pairs of small tubular organs called *nephridia* which serve the purpose. Each one is simply a tube with several coils. There is a pair on the floor of each segment. Each neph-



FIG. 75.—  
GANGLIA  
NEAR MOUTH  
and part of  
nerve chain of  
earthworm.

ridium has an inner open end within the body cavity, and its outer end opens by a pore on the surface between the setæ. The nephridia absorb waste from the liquid in the *celom*, or body cavity surrounding the food tube, and convey it to the outside.

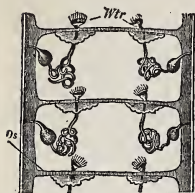


FIG. 76.—TWO PAIRS OF NEPHRIDIA in a worm (diagram).

**Respiration.**—The skin of the earthworm is moist, and the blood capillaries approach so near to the surface of the body that the oxygen is constantly passing in from the air, and carbon dioxide passing out; hence it is constantly breathing through all parts of its skin. *It needs no lungs* nor special respiratory organs of any kind.

**Reproduction.**—When one individual animal produces both sperm-cells and egg-cells, it is said to be hermaphrodite. This is true of the earthworm. The egg-cell is always fertilized, however, not by the sperm-cells of the same worm, but by sperm-cells formed by another worm. The openings of these *ovaries* consist of two pairs of small pores found in most species on the ventral surface of the fourteenth segment (see Fig. 77). There are also two pairs of small *receptacles* for temporarily holding the *foreign sperm-cells*. One pair of the openings from these receptacles is found (with difficulty) in the wrinkle behind the ninth segment (Fig. 77), and the other pair behind the tenth segment. The *spermaries* are in front of the ovaries (Fig. 77), but the *sperm ducts* are longer than the *oviducts*, and open behind them on the fifteenth segment (Figs. 77, 78). The worms exchange sperm-cells, but not

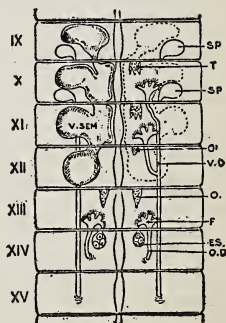


FIG. 77.—Sperm (*sp*) and egg glands (*es*) of worm.

egg-cells. The reproductive girdle, or *clitellum*, already spoken of, forms the case which is to hold the eggs (see Fig. 71). When the sperm-cells have been exchanged, and the ova are ready for fertilization, the worm draws itself backward from the collar-like case or clitellum so that this slips over the head. As it passes the fourteenth segment, it collects the ova, and as it passes the ninth and tenth segments, it collects the sperm-cells previously received from another worm. The elastic, collar-like clitellum closes at the ends after it has slipped over the worm's head, forming a *capsule*. The ova are *fertilized in this capsule*, and some of them hatch into worms in a few days. These devour the eggs which do not hatch. The eggs develop into complete but very small worms before escaping from the capsule.

**Habits.**—The earthworm is *omnivorous*. It will eat bits of meat as well as leaves and other vegetation. It has also the advantage, when digging its hole, of *eating the earth* which must be excavated. Every one has noticed the fresh "casts" piled up at the holes in the morning. As the holes are partly filled by rains, the casts are most abundant after rains. The chief *enemies* of the earthworm are moles and birds. The worms *work at night* and retire so early in the morning that the very early bird has the advantage in catching worms. Perhaps the nearest to an intelligent act the earthworm accomplishes is to *conceal the mouth of its hole* by plugging it with a pebble or a bit of leaf. Worms *hibernate*, going below danger of frost in winter. In dry weather they burrow several feet deep.

The muscular coat of the body wall is much thicker than the skin. It consists of two layers: an outer *layer of fibres which run around the body* just beneath the skin, and an

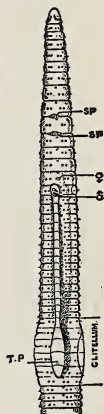


FIG. 78. — Side view, showing setæ, nephridia pores, and reproductive openings.

inner, thicker *layer of fibres which run lengthwise*. The worm crawls by shortening the longitudinal muscles. As the bristles (*setæ*) point backward, they prevent the front part of the body from slipping back, so the hinder part is drawn forward. Next, the circular muscles contract, and the bristles preventing the hind part from slipping back, the fore portion is pushed forward. Is the worm thicker when the hinder part is being pulled up or when the fore part is being thrust forward? Does the earthworm pull or push itself along, or does it do both? Occasionally it travels backward, *e.g.* it sometimes goes backward into its hole. Then the bristles are directed forward.

The right and left halves of the body are counterparts of each other, hence the earthworm is *bilaterally symmetrical*. The lungs and the gills of animals must always be kept moist. The worm *cannot live long in dry air*, for respiration in the skin ceases when it cannot be kept moist, and the worm smothers. Long immersion in water is injurious to it, perhaps because there is far less oxygen in water than in the air.

Darwin wrote a book called "Vegetable Mould and Earthworms." He estimated that there were fifty thousand earthworms to the acre on farm land in England, and that they bring up eighteen tons of soil in an acre each year. As the acids of the food tube act upon the mineral grains that pass through it, the earthworm renders *great aid in forming soil*. By burrowing it makes the soil more *porous* and brings up the subsoil.

Although without eyes, the worm is sensitive to light falling upon its anterior segments. When the light of a lantern suddenly strikes it at night, it crawls quickly to its burrow. Its sense of touch is so keen that it can detect a light puff of breath. Which of the foods kept in a box of

damp earth disappeared first? What is indicated as to a sense of taste?

Why is the bilateral type of structure better adapted for development and higher organization than the radiate type of the starfish? The earthworm's body is a double tube; the hydra's body is a single tube; which plan is more advantageous, and why? Would any other colour do just as well for an earthworm? Why, or why not?

The *sandworm* (*Nereis*) lives in the sand of the seashore, and swims in the sea at night (Fig. 79). It is more advanced in structure than the earthworm, as it has a distinct head (Fig. 80), eyes, two teeth, two lips, and several pairs of antennæ, and two rows of muscular projections which serve as feet. It is much used by fishermen for bait. If more easily obtained, it may be studied instead of the earthworm.



FIG. 79.—SAND WORM  $\times \frac{2}{3}$  (*Nereis*).

**There are four classes in the branch Vermes :**

- 1) the *worms*, including sandworms and leeches; 2) the *roundworms*, including trichina, hairworms, and vinegar eels; 3) *flatworms*, including tapeworm and liver fluke; 4) *rotifers*, which are microscopic aquatic forms.

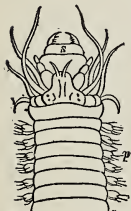


FIG. 80.—HEAD OF SANDWORM (enlarged).

The **tapeworm** is a flatworm which has lost most of its organs on account of its parasitic life. Its egg is picked up by an herbivorous animal when grazing. The embryo undergoes only partial development in the body of the herbivorous animal, *e.g.* an ox. The next stage will not develop until the beef is eaten by a carnivorous animal, to whose food canal it attaches itself and soon develops a long chain of segments called a "tape." Each segment absorbs fluid food through its

body wall. As the segments at the older end mature, each becomes full of eggs, and the segments become detached and pass out of the canal, to be dropped and perhaps picked up by an herbivorous animal, and the life cycle is repeated.

The *trichina* is more dangerous to human life than is the tapeworm. It gets into the food canal in uncooked pork (bologna sausage, for example), multiplies there, migrates into the muscles, causing great pain, and encysts there, remaining until the death of the host. It is believed to get into the bodies of hogs again when they eat rats, which in turn have obtained the cysts from carcasses.

**Summary of the Biological Process.**—An earthworm is *a living machine which does work* (digging and crawling; seizing, swallowing, and digesting food; pumping blood; growing and reproducing). To do the work it must have a continual *supply of energy*. The energy for its work is set free by the protoplasm (in its microscopic cells) undergoing a destructive chemical change (*oxidation*). The waste products from the breaking down of the protoplasm must be continually removed (*excretion*). The broken-down protoplasm must be continually replaced if life is to continue (the income must exceed the outgo if the animal is still growing). The microscopic cells construct more protoplasm out of food and oxygen (*assimilation*) supplied them by the processes of nutrition (eating, digesting, breathing, circulating). This protoplasm in turn oxidizes and releases more energy to do work, and thus the cycle of life proceeds.



## CHAPTER VII

### CRUSTACEANS

#### CRAYFISH

**SUGGESTIONS.**—In regions where Crayfish are not found, a live crab may be used. Locomotion and behaviour may be studied by providing a tub of water, or better, a large glass jar such as a broad candy jar. For suggestions on study of internal structure, see p. 58.

**Habitat.** — Do you often see crawfish, or crayfish, moving about, even in water where they are known to be abundant? What does your answer suggest as to the time when they are probably most active?

Why do you never see one building its chimney, even where crayfish holes are abundant? Is the chimney always of the same colour as the surface soil? Are the crayfish holes only of use for protection? In what kind of spots are crayfish always dug? Why? What becomes of crayfish when the pond or the creek dries up? How deep are the holes? How large are the lumps of mud of which the chimney is built? How does it get them out of the hole? Why is the mud built into a chimney instead of thrown away? (What would happen to a well with its mouth no higher than the ground?) Why are crayfish scarce in rocky regions?

How does the colour of the crayfish compare with its surroundings? Is its colour suited to live in clear or muddy water? Define protective coloration.

**Habits.**— Does the crayfish walk better in water or out of it? Why? Does it use the legs with the large claws to assist in walking? Do the swimmerets (under the abdomen) move fast or slow? (Observe it from below in a large jar of clear water.) What propels it backward? Forward? Does the crayfish move at a more uniform rate when swimming backward or forward? Why? In which way can it swim more rapidly? Do the big legs with claws offer more resistance to the water while it is swimming backward or forward? How does it hold the tail after the stroke, while it is darting backward through the water? Hold a crayfish with its tail submerged and its head up. Can the tail strike the water with much force? Allow it to grasp a pencil: can it sustain its own weight by its grip?

**Feeding.**—Offer several kinds of food to a crayfish that has not been alarmed or teased. Does it prefer bread, meat, or vegetables? How does it get the food to its mouth? Does it eat rapidly or slowly? Does it tear the food with the big pincers? Can it gnaw with the small appendages near the mouth?

**Breathing.**—Does the crayfish breathe with gills or lungs? Place a few drops of ink near the base of the hind legs of a crayfish resting quietly in shallow water. Where is the ink drawn in? Where does it come out? To explain the cause and the purpose of this motion, place a crayfish in a large glass jar containing water, and see the vibratory motion of the parts under the front portion of the body. There is under the shell on each side of the body a gill paddle, or gill bailer, that moves at the same rate.

**Senses.**—Crayfish are best caught with a piece of meat or beef's <sup>tail</sup> tied to a string. Do they always lose hold as soon as they are lifted above the water? What do you

conclude as to the alertness of their senses? Does the covering of their bodies suggest the possession of a delicate or a dull sense of touch?

Of what motions are the *eyes* capable? Touch one of the eyes. The result? Can a crayfish see in all directions? To test this, place a crayfish on a table and try whether you can move to a place where you can see the



FIG. 81. — CRAYFISH  
(dorsal surface).

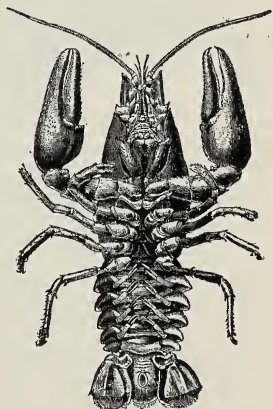


FIG. 82.

crayfish without seeing its eyes. What are the advantages and disadvantages of having the eyes on stalks?

Touch the body and the several appendages of the crayfish. Where does it seem most sensitive to *touch*? Which can reach farther, the antennæ or the big claws? Why are short feelers needed as well as long ones?

Make a loud and sudden noise without jarring the crayfish. Is it affected by *sound*?

**External Anatomy** (Figs. 81, 82, 83, 84).—Is the body of the crayfish rounded out (convex) everywhere or is any part of its surface either flat or rounded in (concave)?

What *colour* has the crayfish? Is this colour of any use to the crayfish?

Make out the two distinct regions or *divisions of the body* (Fig. 81). The anterior (front) region is called the head-chest or cephalothorax, and the posterior (rear) region is

called the tail.

Which region is

larger? Why?

Which is flexible? Why?

Is the *covering* of the body hard or soft? What

is the advantage of such a covering? What are its disadvantages? How is the covering modified at the joints to permit motion?

**Tail.**—How many joints, or segments, of the tail? (Figs. 81, 83.) Does the hard covering of each segment slip under or over the segment behind it when the tail is straight? Does this lessen friction while swimming forward?

Is there a pair of *swimmerets* to each segment of the tail? (Figs. 82, 86.)

Notice that each swimmeret has a main stalk (protopod), an outer branch (exopod), and an inner branch (endopod) (Fig. 84).

Are the stalk and the branches each in one piece or jointed? The middle part of the tail fin is called the telson. By finding the position of the vent, decide whether the food tube goes into the telson (Fig. 82). Should it be called an abdominal segment? Are the side pieces of the tail fin attached to the telson or to the sixth segment? Do these side pieces correspond



FIG. 83.—LATERAL VIEW OF CRAYFISH.



FIG. 84.—  
FOURTH ABDOMINAL SEGMENT  
OF CRAYFISH  
with swimmeret.

to swimmerets? Do they likewise have the Y-shaped structure? (Fig. 86.)

If the swimmerets on the first abdominal segment are large, the specimen is a male. If they are small, it is a female. Which sex is shown in Fig. 82? Fig. 86?

**Carapace.** — The covering of the head chest (cephalothorax) is called the carapace. Has it free edges? The *gills* are on the sides of the body and are covered by the carapace (Fig. 87). The projection in front is called the *rostrum*, meaning beak. Does the rostrum project beyond the eyes? There is a transverse groove across the carapace which may

be said to divide the head from the abdomen. Where

does this groove end at the sides?

**Legs.** — How many legs has the crayfish? How many are provided with large claws? Small claws? Is the outer claw hinged in each of the large grasping pincers? The inner claw?

**Appendages for Taking Food.** —

If possible to watch a living crayfish eating, notice whether it places

the food directly into the mouth with the large claws. Bend the large claws under and see if they will reach the mouth.

Attached just in front of the legs the crayfish has three pairs of finger-like appendages, called foot jaws (maxillipeds), with which it passes the food from the large pincers

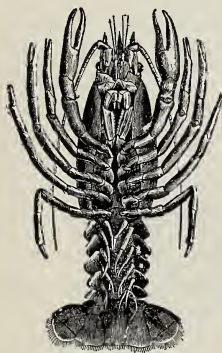


FIG. 86.—CRAYFISH  
(ventral surface).



FIG. 85.—1, mandible; 2, 3, maxillae; 4, 5, 6, maxillipeds.

to its mouth (Figs. 85, 86.) They are in form and in use more like fingers than feet. In front of the foot jaws are two

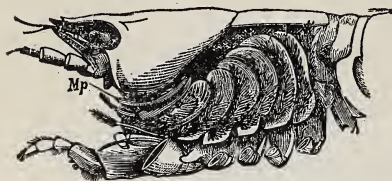


FIG. 87. — Gill cover removed and gills exposed.

*Mp*, gill bailer.

pairs of thin jaws (maxillæ) and in front of the thin jaws are a pair of stout jaws (mandibles) (Fig. 85). Do the jaws move sidewise or up and down? Which of the jaws has a

jointed finger (palp) attached to it? Do all the appendages for taking food have both exopod and endopod branches on a basal stalk or protopod? Which of the appendages have a scalloped edge? How would you know from looking at the crayfish that it is not merely a scavenger? Why are there no pincers on the hind feet?

**Sense Organs.** — Find the *antennæ*, or long feelers (Figs. 82, 90). Are the *antennæ* attached above or below the eyes? (Fig. 87.)

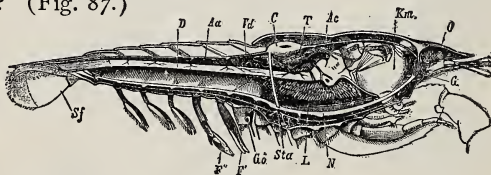


FIG. 88. — LENGTHWISE SECTION OF MALE CRAYFISH

*c*, heart; *Ac*, artery to head; *Aa*, artery to abdomen; *Km*, stomach; *D*, intestine; *L*, liver; *T*, spermary; *Go*, opening of sperm duct; *G*, brain; *N*, nerve chain.

Find the pair of *antennules*, or small feelers. Are their divisions like or unlike each other? Compare the length of the antennules and the *antennæ*. Compare the flexibility of the *antennæ* with that of the other appendages.



Observe the position of the *eyes* (Figs. 81, 88). How long are the eyestalks? Is the stalk flexible or stiff? Touch the eye. Where is the joint which enables the stalk to move? Is the outer covering of the eye hard or soft? A mounted preparation of the transparent covering (cornea) of the eye, seen with lower power of microscope, reveals that the cornea is made up of many divisions, called facets. Each facet is the front of a very small eye, hundreds of which make up the whole eye, which is therefore called a compound eye. The elongated openings to the *ear sacs* are located each on the upper side of the base of a small feeler just below the eye.

**Respiratory System.** — The respiratory organs are gills located on each side of the thorax in a space between the carapace and the body (Fig. 87). The gills are white, curved, and feathery. Is the front gill the largest or the smallest? The gills overlap each other; which is the outermost gill? On the second maxilla is a thin, doubly curved plate called a gill bailer (Fig. 85). The second maxilla is so placed that the gill bailer comes at the front end of the gill chamber. The bailer paddles continually, bringing the water forward out of the gill. The gills are attached below at the base of the legs. Are the gills thick or thin? How far upward do they go? Does the backward motion in swimming aid or hinder the passage of the water through the gills? Does a crayfish, when at rest on the bottom of a stream, have its head up or down stream? Why?

**Openings.** — The slitlike *vent* is on the under side of the telson (Figs. 82, 88). The *mouth* is on the under side of the thorax behind the mandibles. At the base of the long antennæ are the openings from the *green glands*, two glands in the head which serve as kidneys (Fig. 89). The openings of the *reproductive organs* are on the third



FIG. 89. — Level length-wise section showing

- h*, heart.
- d*, green gland.
- le*, liver.
- kie*, gills.
- hh*, gill cavity.
- ma*, stomach.

(After Huxley.)

to the vent. Is it large or small? Straight or curved? The powerful flexor muscles of the tail lie in the abdomen below the intestines. Compare the size of these muscles with the extensor muscle above the intestine (Fig. 90). Why this difference? Does the food tube extend into the telson? Locate the vent (Fig. 90).

pair of legs in the female, and the fifth pair of legs in the male (Fig. 88). The eggs are carried on the swimmerets.

**Internal Structure.** — **SUGGESTIONS.** If studied by dissection, it will be necessary to have several crayfish for each pupil, one for gaining general knowledge, and others for studying the systems in detail. Specimens should have lain in alcohol for several days.

**The Food Tube.** — Is the stomach in the head portion of the cephalothorax or in the thoracic portion? (Figs. 88, 89). Is the stomach large or small? What is its general shape? Does the gullet lead upward or backward? Is it long or short? (Fig. 88.) The mid tube, which is the next portion of the food tube, is smaller than the stomach. On each side of it are openings from the bile ducts which bring the secretion from the digestive gland, sometimes called the liver. Does this gland extend the whole length of the thorax? Is it near the floor or the top of the cavity? The third and last portion of the food tube is the intestine. It extends from the thorax

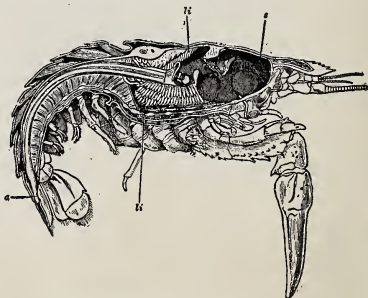


FIG. 90. — SECTION OF CRAYFISH showing—  
stomach *s*, liver *li*, and vent *a*.

**The Circulation.** — The blood is a liquid containing *white corpuscles*. It lacks red corpuscles and is colourless. The heart is in the upper part of the thorax. It is surrounded by a large, thin bag, and thus it is in a chamber (called the *pericardial sinus*). The blood from the pulmonary veins enters this sinus before it enters the heart. The origin of this pericardial sinus by the fusing of veins is shown in Fig. 130. Does one artery, or do several arteries, leave the heart? There is a larger dorsal artery lying on the intestine and passing back to the telson; there are three arteries passing forward close to the dorsal surface (Figs. 89, 91). One large artery (the sternal) passes directly downward (Figs. 88, 91), and sends a branch forward and another backward near the ventral surface. The openings into the heart from the sinus have valvular lips which prevent a backward flow of blood into the sinus. Hence, when

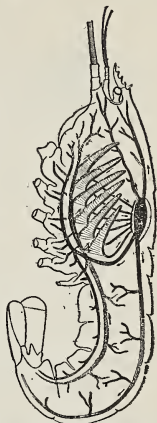


FIG. 91. — Showing heart and main blood-vessels.



FIG. 92.

the heart contracts, the blood is sent out into the several arteries. The arteries take a supply of fresh blood to the eyes, stomach, muscles, liver, and the various organs. After it has given oxygen to the several organs and taken up carbon dioxide, it returns by veins to pass through the gills on each side, where it gives out the useless gas and takes up oxygen from the water. It is then led upward by veins into the pericardial sinus again.

The central nervous system consists of a *double chain* of ganglia (Fig. 92). This main nerve chain lies along the ventral surface below the food tube (Fig. 90), except one pair of ganglia which lie above the œsophagus or gullet (Fig. 88), and are called the supra-œsophageal ganglia, or brain.

**Crustacea.** — The crayfish and its kindred are placed in the class called *Crustacea*.

**Decapods.** — All crustacea which have ten feet belong in the order called decap'oda (ten-footed). This order includes the crabs, lobsters, shrimp, etc. The crabs and the lobsters are of considerable importance because of use as food. Small boys sometimes catch crayfish, and in some instances are known to cook and eat them for amusement,



FIG. 93. — CRAB FROM BELOW.

the only part cooked being the muscular tail. The crab's tail is small and flat and held under the body (Fig. 93).

Since the limy covering to serve the purpose of protection is not soft enough to be alive and growing, it is evident that the crustacea are hampered in their growth by their crusty



FIG. 94. — HERMIT CRAB, using shell of sea-snail for a house.

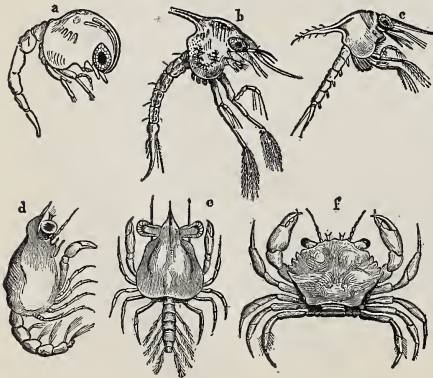


FIG. 95. — DEVELOPMENT OF A CRAB.

*a*, nauplius just after hatching; *b, c, d*, zoea; *e*, megalops; *f*, adult.

**Question:** Which stage is most like a crayfish? Compare with metamorphoses of insects.

covering. During the first year the crayfish sheds its covering, or moults three times, and once each year thereafter. It grows very fast for a few days just after moulting, while the covering is soft and extensible. Since it is at

the mercy of birds, fish, and other enemies while in this soft and defenceless condition, it stays hidden until the covering hardens. Hence it cannot eat much, but probably by the absorption of water the tissues grow; that is, enlarge. In the intervening periods, when growth is impossible, it develops; that is, the tissues and organs change in structure and become stronger. "Soft-shelled crab" is a popular dish, but there is no species by that name, this being only a crab just after moulting which has been found by fishermen in spite of its hiding.

**General Questions**—How do crayfish choose their food? How long can they live out of water? Why do their gills remain moist out of water longer than a fish? How do they breathe out of water? Are they courageous or cowardly animals? When they lose appendages in fighting or moulting, these are readily reproduced, but an organ moults several times in regaining its size. Have you seen crayfish with one claw smaller than the other? Compare the crayfish and crab (Figs. 81, 93, and 95) in the following particulars: shape, body, eyes, legs, abdomen, habitat, movement.

#### KEY TO THE FOUR CLASSES IN BRANCH ARTHROPODS

1. INSECTS . . . 3 body divisions, 6 legs
2. ARACHNIDS . . . 2 body divisions, 8 legs
3. MYRIAPODS . . . many body divisions, many legs
4. CRUSTACEANS . . . gill breathers, skeleton (external) limy

By the aid of the key and of figures 96-105, classify the following Arthropods: tick, thousand-leg centipede, king crab, pill bug, spider, scorpion, beetle.



FIG. 96. — PILL  
BUG.



FIG. 97. —  
LADY  
BEETLE.



FIG. 98. — SCORPION.



FIG. 101. — ONE SEG-  
MENT OF CENTIPEDE  
with one pair of legs.



FIG. 99. — TICK  
before and after  
feeding.



FIG. 100. —  
CENTIPEDE.



FIG. 102. —  
ONE SEGMENT  
OF THOUSAND  
LEGS with two  
pairs of legs.

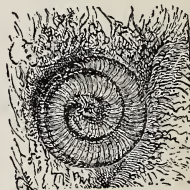


FIG. 103. — THOUSAND  
LEGS.

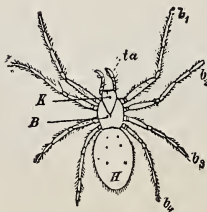


FIG. 104. — A SPIDER.

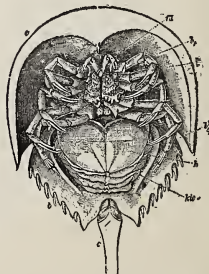


FIG. 105. — KING CRAB.



## CHAPTER VIII

### INSECTS

#### THE GRASSHOPPER

**SUGGESTIONS.** — Collect grasshoppers, both young and full-grown, and keep alive in broad bottles or tumblers and feed on fresh grass or lettuce. When handling a live grasshopper, never hold it by its legs, as the joints are weak. To keep them for some time and observe their moults, place sod in the bottom of a box and cover the box with mosquito netting or wire gauze.

What is the **general shape** of its body? (Fig. 106.) Where is the body thickest? Is it bilaterally symmetrical, that is, are the two sides of the body alike? Is the *skeleton*, or hard part of the body, internal or external? Is the skeleton as stiff and thick as that of a crayfish? What is the length of your specimen? Its colour? Why does it have this coloration? In what ways does the grasshopper resemble the crayfish? Differ from it?



FIG. 106. — A GRASSHOPPER.

**The Three Regions of the Body.** — The body of the grasshopper is divided into three regions — the *head*, the *thorax*, and the *abdomen*. Which of these three divisions has no distinct subdivisions? The body of the grasshopper, like that of the earthworm, is made of *ringlike segments*. Are the segments most distinct in the head, the thorax or the abdomen? Which region is longest? Shortest? Strongest? Why? Which region bears the chief sense organs? The appendages for taking food? The locomotory appendages? Which division of the body is most active in breathing?

**The Abdomen.** — About how many segments or rings in the abdomen? Do all grasshoppers have the same number of rings? (Answer for different species and different individuals of the same species.) The first segment and the last two are incomplete rings. Does the flexibility of the abdomen reside in the rings or in the joints between the rings? Is there merely a thin, soft line between the rings, or is there a fold of the covering? Does one ring slip into the ring before it or behind it when the abdomen is bent?

As the grasshopper **breathes**, does each ring enlarge and diminish in size? Each *ring is divided into two parts*

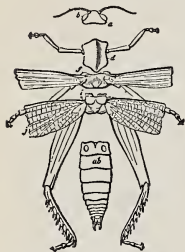


FIG. 107. — A GRASSHOPPER DISSECTED.

by folds. Does the upper half-ring overlap the lower half-ring, or the reverse? With magnifying glass, find a small slit, called a *spiracle*, or breathing hole, on each side of each ring just above the side groove (Fig. 106). A tube leads from each spiracle. While the air is being taken in, do the two portions of the rings move farther apart? When they are brought together again, what must be the

effect? In pumping the air, the abdomen may be said to work like a bellows. Bellows usually have folds to allow motion. Is the comparison correct?

How many times in a minute does the grasshopper take in air? If it is made to hop vigorously around the room and the breathing is again timed, is there any change?

Find the **ears** on the front wall of the *first abdominal ring* (Fig. 107). They may be seen by slightly pressing the abdomen so as to widen the chink between it and the thorax. The ears are merely glistening, transparent *membranes*, oval in form. A *nerve* leads from the inner

surface of each membrane. State any advantage or disadvantage in having the ears located where they are.

**Ovipositor.** — If the specimen is a female, it has an egg-placer or ovipositor, consisting of *four blunt projections* at the end of the abdomen (Fig. 107). If it is a male, there are two appendages above the end of the abdomen, and smaller than the parts of the ovipositor. Females are larger and more abundant than males. In laying the eggs, the four blunt points are brought tightly together and then forced into the ground and opened (Fig. 108). By repeating this, the grasshopper makes a pit almost as deep as the abdomen is long. The eggs are laid in the bottom of the pit.

**Draw** a side view of the grasshopper.

**Thorax.** — This, the middle portion of the body, consists of *three segments* or rings (Fig. 107). Is the division between the rings most apparent above or below? Which two of the three rings are more closely united?

The front ring of the thorax is called *prothorax*. Is it larger above or below? Does it look more like a collar or a cape? (Fig. 106.) A spiracle is found on the second ring (*mesothorax*, or middle thorax) just above the second pair of legs. There is another in the soft skin between the prothorax and the mesothorax just under the large cape or collar. The last ring of the thorax is called the *metathorax* (rear thorax).

How many legs are attached to each ring of the thorax? Can a grasshopper walk? Run? Climb? Jump? Fly? Do any of the legs set forward? (See Fig. 106.)

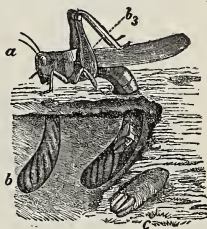


FIG. 108. — GRASSHOPPER LAYING EGGS. (Riley.)

Outward? Backward? Can you give reasons for the position of each pair? (Suggestion: What is the use of each pair?) If an organ is modified so that it is suited to serve some particular purpose or function, it is said to be *specialized*. Are any of the legs specialized so that they serve for a purpose different from that of the other legs?

The leg of a grasshopper (as of all insects) is said to have *five parts*, all the small parts after the first four parts being counted as one part and called the foot. Are all the legs similar, that is, do the short and the long joints in all come in the same order? Numbered in order from the

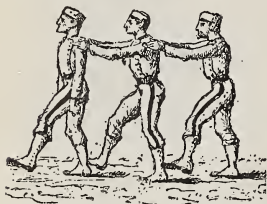


FIG. 109. — HOW A GRASSHOPPER WALKS.



FIG. 110. — HOW A SPIDER WALKS.

body, which joint of the leg is the largest — the first, second, third, or fourth? Which joint is the shortest? The slenderest? Which joint has a number of sharp points or spines on it? Find by experiment whether these spines are of use in walking (Fig. 106). Jumping. Climbing. In what order are the legs used in walking? How many legs support the body at each step?

All animals that have ears have ways of communicating by sounds. Why would it be impossible for the grasshopper to have a *voice*, even if it had vocal cords in its throat? The male grasshoppers of many species make a **chirping**, or stridulation, by rubbing the wing against the leg. Look on the inner side (why not outer side?) of the

largest joint of the hind leg for a *row of small spines* visible with the aid of a hand lens (Fig. 111). The sound is produced by the outer wings rubbing against the spines. Have you noticed whether the sound is produced while the insect is still or in motion? Why? The male grasshoppers of some species, instead of having spines, rub the under side of the front wing on the upper side of the hind wing.

**Wings.** — To what is the first pair of wings attached? The second pair? Why are the wings not attached to the prothorax? Why are the wings attached so near the dorsal line of the body? Why are the second and third rings of the thorax more solidly joined than the first and second rings?

Compare the first and second pairs of wings in shape, size, colour, thickness, and use (Fig. 112). How are the second wings folded so as to go under the first wings? About how many folds in each?

**Draw** a hind wing opened out.

**Head.** What is the shape of the head viewed from the front, the side, and above? *Make sketches.* What can you say of the neck? Is the head movable in all directions?

What is the position of the large eyes? Like the eyes of the cray-

fish, they are *compound, with many facets*. But the grasshopper has also *three simple eyes*, situated one in the middle of the forehead and one just above each antenna. They are too small to be seen without a hand lens. How does

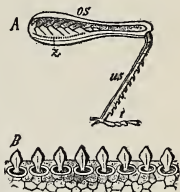


FIG. 111. — A, ROW OF SPINES, z, used in chirping.

B, the same more enlarged.



FIG. 112. — GRASSHOPPER IN FLIGHT.

the grasshopper's range of vision compare with that of the crayfish?

Are the antennæ flexible? What is their shape? Position? Are they segmented? Touch an antenna, a wing, a leg, and the abdomen in succession. Which seems to be



FIG. 113.

the most sensitive to touch? The antennæ are for feeling. In some species of insects they also are organs of hearing and smelling.

The mouth parts of a grasshopper should be compared with the mouth parts of a beetle shown in Fig. 113, since they correspond closely. If the grasshopper is fed with a blade of fresh grass, the function of each organ may be plainly seen. It is almost impossible to understand these functions by studying a dead specimen, and a fresh specimen is much better than a dry one.

The upper lip, or *labrum*, is seen in front. Is it tapering or expanded? In what direction is it movable? The dark pointed biting jaws (*mandibles*) are next. Are they curved



FIG. 114. — a, FOOD TUBE OF BEETLE.

b, gizzard; c, intestine; d, biliary vessels. See Fig. 127.

or straight? Sharp or blunt pointed? Notched or smooth? Do they work up and down, or sideways? The holding jaws (*maxillæ*), each with two jaw fingers (*maxillary palpi*), are behind the chewing jaws. Why? The lower lip (*labium*) has a pair of lip fingers (*labial palpi*) upon it. The brown



tongue, usually bathed in saliva, is seen in the lower part of the mouth. Since the grasshopper has no lips, or any way of producing suction, it must lap the dew in drinking. Does it merely break off bits of a grass blade, or does it chew?

The heart, circulation, nervous system, digestive and respiratory organs of the grasshopper agree mainly with the general description of the organs of insects given in the next section.

**Microscopic Objects.** — These may be bought ready mounted, or may be examined fresh. A portion of the covering of the large eye may be cut off and the dark layer on the inside of the covering scraped off to make it transparent. What is the shape of the facets? Can you make any estimate of their number? A portion of the transparent hind wing may be used, and the "veins" in it studied. A

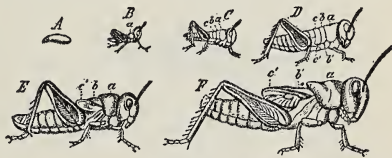


FIG. 115.—EGG AND MOULTS OF A GRASSHOPPER.

thin bit of an abdominal segment containing a spiracle will show the structure of these important organs.

**Growth of the Grasshopper.** — Some species hibernate in sheltered places and lay eggs in the spring, but adult species are scarce at that season. Most species lay the eggs in the fall; these withstand the cold and hatch out in the spring. Those hatched from one set of eggs sometimes stay together for a few days. They eat voraciously, and as they grow, the soft skin becomes hardened by the deposit of horny substance called chitin. This retards further growth until the insect moults, the skin first splitting above the prothorax. After hatching, there are five successive periods of growth. At which moult do the very short wings first appear? (Fig. 115)

After the last moult the animal is complete, and changes no more in size for the rest of its life. There has been an



FIG. 116. —  
COCKROACH.

attempt among writers to restrict the term grasshopper to the long-winged, slender family, and to call the shorter winged, stouter family locusts, according to old English usage.

#### **Economic Importance of Grasshoppers. —**

Great injury is often done to vegetation by grasshoppers; however, the millions of tiny but ravenous eaters hatched in early spring are usually soon thinned out by the birds. The migratory locusts constitute a plague when they appear, and



FIG. 117. — PRAYING MANTIS, or devil's horse.



FIG. 118. — CRICKET.

they have done so since ancient times. The Rocky Mountain locusts flying eastward have darkened the sky, and where they settled to the earth ate almost every green thing.

In 1874-5 they produced almost a famine in Kansas, Nebraska, and other Western states. The young hatched away



FIG. 119. — MOLE CRICKET.

from the mountains were not healthy, and died prematurely, and their devastations came to an end. Of course the migrations may occur again. Packard calculates that the farmers of the West lost \$200,000,000 because of grasshopper ravages in 1874-5.



FIG. 120. — FRONT  
LEG OF MOLE  
CRICKET.  $\times 3$ .

The *cockroaches* (Fig. 116), kindred of the grasshoppers, are household pests that have migrated almost everywhere that ships go. The *praying mantis* (Fig. 117), or *devil's horse*, also belongs to this order. It is beneficial, since it destroys noxious insects. Which of its legs are specialized? The *walking stick* (Fig. 121) and the *cricket* (Fig. 118), like most members of the order, are vegetarian.

Are grasshoppers more common in fields and meadows, or in wooded places? How many different colours have you seen on grasshoppers? Which colours are most common?

Grasshoppers are very scarce in Europe as they love dry, warm countries. Why do locusts migrate? Give an instance in ancient times.

How long do most grasshoppers live? Does a grasshopper spread its wings before it flies? Does it jump and fly together? Can it select the place for alighting?



FIG. 121. — FOUR WALKING STICK INSECTS.

NOTE TO TEACHER. — Field work in Zoology should be systematic. Every trip has a definite region and definite line of study in view, but every animal seen should be noted. The habitat, adaptation by structure and habits to the environment, relations to other animals, classification of animals seen, should be some of the ideas guiding the study. The excursions may be divided somewhat as follows, according as opportunities offer: Upland woods, lowland woods, upland pastures, fields, swamps, a fresh-water lake, a pond, lower sea beach, higher sea beach, sand hills along shore, roadside, garden, haunts of birds, insect visits to flowers, ground insects, insects in logs.

**Collecting Insects.**—In cities and towns, insects, varying with the season, are attracted by electric lights. Beetles and bugs will be found under the lights, moths on posts near the lights, grasshoppers and crickets and other insects in the grass near by. A lamp placed by a window brings many specimens. In the woods and in rocky places, insects are found under logs and stones and under the bark of dead trees. In open places, prairies, meadows, and old fields with grass and flowers, it will be easy to find grasshoppers, butterflies, and some beetles. Ponds and streams are usually rich in animal forms, such as bugs and beetles, which swim on or under the surface, and larvæ of dragon-flies crawling on the bottom. Dragon-flies and other insects that lay eggs on the water are found flying in the air above. (In the spring, newly hatched crayfish, tadpoles, and the eggs of frogs and toads should also be collected, if found.) Moths may be caught at night by daubing molasses or syrup made from brown sugar upon the trunks of several trees, and visiting the trees at intervals with a lantern.

An insect net for catching butterflies and for dredging ponds may be made by bending a stout wire into a circle one foot in diameter, leaving enough straight wire to fasten with staples on an old broomstick. To the frame is fastened a flour sack, or cone made of a piece of mosquito netting.

Butterflies and moths should be promptly killed, or they will beat their wings to pieces. The quickest method is by dropping several drops of gasoline upon the ventral (under) side of the thorax and abdomen. (Caution: Gasoline should never be used near an open fire, or lamp, as explosions and deaths result from the flame being led through the gasoline-saturated air to the vessel containing it.)

A cigar box and a bottle with a notched cork may be used for holding specimens. Cigar boxes may be used for holding collections of dried insects. Cork or ribbed packing paper may be fixed in the bottom for supporting the insect pins. Moth balls or tobacco may be placed in each box to keep out the insect pests which infest collections.

Captured insects which, in either the larval or the perfect stage, are injurious to vegetation, should always be killed after studying their actions and external features, even if the internal structure is not to be studied. Beneficial insects, such as ladybugs, ichneumon flies, bees, mantis (devil's horse), dragon-flies, etc., should be set free uninjured.

#### ANATOMY AND GENERAL CHARACTERISTICS OF THE CLASS INSECTA

The body of an insect is divided by means of two marked narrowings into three parts: the head, the chest, and the abdomen.

The head is a freely movable capsule bearing four pairs of appendages. Hence it is regarded as having been formed by the union of four rings, since the *ancestor of the insects* is believed to have consisted of similar rings, each ring bearing a pair of unspecialized legs.

The typical mouth parts of an insect (Fig. 123) named in order from above, are (1) an upper lip (labrum, *ol*), (2) a pair

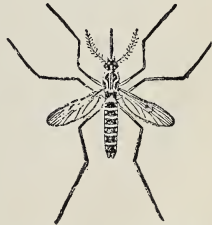


FIG. 122. — YELLOW FEVER MOSQUITO, showing head, thorax, abdomen.

of biting jaws (mandibles, *ok*), (3) a pair of grasping jaws (maxillæ, *A*, *B*), and (4) a lower lip (labium, *m*, *a*, *b*).

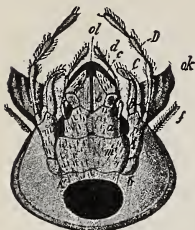


FIG. 123. — MOUTH PARTS OF BEETLE.

Why are the fingers (or palpi) jointed? (Watch a grasshopper or beetle eating.) Why does an insect need grasping jaws?

The chest, or **thorax**, consists of three rings (Fig. 124) called the front thorax (prothorax), middle thorax (mesothorax) and hind thorax (metathorax), or first, second, and third rings.



FIG. 125. — LEG OF INSECT.

The grasping jaws bear two pairs of jointed jaw fingers (maxillary palpi, *D*, *C*), and the lower lip bears a pair of similar lip fingers (labial palpi, *d*). The biting jaws move sideways; they usually have several pointed notches which serve as teeth. Why should the grasping jaws be beneath the chewing jaws? Why is it better for the lower lip to have fingers than the upper lip?



FIG. 124. — EXTERNAL PARTS OF A BEETLE.

The first ring bears the first pair of legs, the second ring bears the second pair of legs and the upper or front wings, and the third ring bears the third pair of legs and the under or hind wings.

Thesix feet of insects are characteristic of them, since no other adult animals have that number, the spider having eight, the cray-fish and crabs having ten, the centipedes still more, while birds and beasts have less than six. Hence the insects



are sometimes called the Six-Footed class (*Hexapoda*). The insects are the only animals that have the **body in three divisions**. Man, beasts, and birds have only two divisions (head and trunk). Worms are not divided.

**Define** the class *insecta* by the two facts characteristic of them (*i.e.* possessed by them alone), viz. : Insects are animals with ——— and ———. Why would it be ambiguous to include "hard outer skeleton" in this definition? To include "bilateral symmetry"? "Segmented body"? The definition of a class must *include* all the individuals of the class, and *exclude* all the animals that do not belong to the class.

The leg of an insect (Fig. 125) has five joints (two short joints, two long, and the foot). Named in order from above, they are (1) the hip (coxa), (2) thigh ring (trochanter), (3) thigh (femur), (4) the shin (tibia), (5) the foot, which has five parts. Which of the five joints of a wasp's leg (Fig. 161) is thickest? Slenderest? Shortest? One joint (which?) of the foot (Fig. 161) is about as long as the other four joints of the foot combined. Is the relative length of the joints of the leg the same in grasshoppers, beetles, etc., as in the wasp (Figs.)? Figure 125 is a diagram of an insect's leg cut lengthwise. The leg consists of thick-walled tubes (*o*, *n*) with their ends held together by thin, easy-wrinkling membranes which serve as joints. Thus motion is provided for at the expense of strength. When handling live insects they should never be held by the legs, as the legs come off very easily. Does the joint motion of insects most resemble the motion of hinge joints or ball-and-socket joints? Answer by tests of living insects. There are no muscles in the foot of an insect. The claw is moved by a muscle (*m*) in the thigh with which it is connected by the long tendon (*z*, *s*, *t*, *v*). In which part are the breathing muscles? As the wings are developed from folds of the dorsal skin, the wing has two layers, an upper and a lower layer. These inclose the so-called "nerves" or ribs of the wing, each of which consists of a blood tube inclosed in an air tube.



FIG. 126. — FOOT OF FLY, with climbing 'pads.

The abdomen in various species consists of from five to eleven overlapping rings with their foldlike joints between them. Does each ring overlap the ring in front or the one behind it?

The food tube (Fig. 127) begins at the mouth, which usually bears salivary glands (4, Fig. 127, which represents internal organs of the grasshopper). The food tube expands first into a *croplike* enlargement; next to this is an organ (6, Fig. 127), which resembles the gizzard

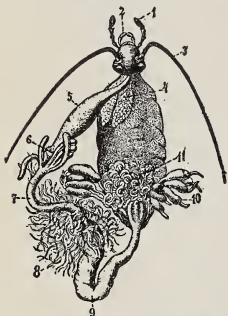


FIG. 127.—VISCERA OF GRASSHOPPER. Key in text. Compare with Fig. 114.

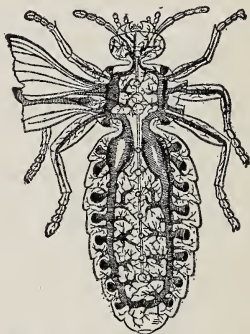


FIG. 128.—AIR TUBES OF INSECT.

in birds, as its inner wall is furnished with chitinous teeth (*b*, Fig. 114). These reduce the food fragments that were imperfectly broken up by the biting jaws before swallowing. *Glands* comparable to the liver of higher animals open into the food tube where the stomach joins the small intestine. At the junction of the small and the large intestine (9) are a number of *fine tubes* (8) which correspond to *kidneys* and empty their secretion into the large intestine.

The **breathing organs** of the insects are peculiar to them (see Fig. 128). They consist of tubes which are

kept open by having in their walls continuous spirals of horny material called *chitin*. Most noticeable are the two large membranous tubes filled with air and situated on each side of the body. Do these tubes extend through the thorax? (Fig. 128.) The air reaches these two main tubes by a number of pairs of short windpipes, or *tracheas*, which begin at openings (*spiracles*). In which division are the spiracles most numerous? (Fig. 128.)

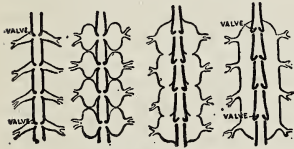


FIG. 130.—DIAGRAMS OF EVOLUTION OF PERICARDIAL SAC around insect's heart from a number of veins (Lankester).

Which division is without spiracles?

Could an insect be drowned, *i.e.*

smothered, by holding its body under water? Could it be drowned by immersing all of it but its head? The motion of the air through

the breathing tubes is caused by a bellowslike *motion of the abdomen*. This is readily observed in grasshoppers, beetles, and wasps. As each ring slips into the ring in front of it, the abdomen is shortened, and the impure air, laden with carbon dioxide, is forced out. As the rings slip out, the abdomen is extended and the fresh air comes in, bringing oxygen.

### The Circulation. —

Near the dorsal surface of the abdomen (Fig.

131) extends the long, slender *heart* (Fig. 129). The heart has divisions separated by valvelike partitions. The blood comes into each of the heart compartments through a pair of openings. The heart contracts from the rear toward



FIG. 129.  
INSECT'S  
HEART  
(plan).



FIG. 131.—POSITION OF INSECT'S HEART, food tube, and nerve chain.

the front, driving the blood forward. The blood contains bodies corresponding to the *white corpuscles* of human blood, but lacks the red corpuscles and the red colour. The blood is sent even to the wings. The veins in the wings consist of horny tubes inclosing air tubes surrounded by blood spaces, and the purification of the blood takes place throughout the course of the circulation. Hence the imperfect circulation is no disadvantage. The perfect provision for supplying oxygen explains the remarkable activity of which insects are capable and their great strength, which, considering their size, is unequalled by any other animals.

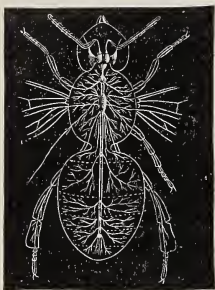


FIG. 132. — NERVOUS SYSTEM OF BEE.

**The Nervous System.** — The heart in backboneed animals, *e.g.* man, is ventral and the chief nerve trunk is dorsal. As already stated, the heart of an insect is dorsal; its chief nerve chain, consisting of a *double row of ganglia*, is near the ventral surface (Fig. 131). All the ganglia are below the food tube except the first pair in the head, which are above the gullet. This pair may be said to correspond somewhat to the brain of backboneed animals; the nerves from the eyes and the feelers lead to it. With social insects, as bees and ants, it is large and complex (Fig. 132). In a typical insect they are the largest ganglia.

**The Senses.** — The sense of *smell* of most insects is believed to be located in the feelers.

The organ of *hearing* is variously located in different insects. Where is it in the grasshopper? The organs of



FIG. 133. — FEELER of a beetle.

*sight* are highly developed, and consist of two compound eyes on the side of the head and three simple eyes on the top or front of the head between the compound eyes. The simple eye has nerve cells, pigments, and a lens resembling the lens in the eyes of vertebrates (Fig. 134). The compound eye (Fig. 135) has thousands of facets, usually hexagonal, on its surface, the facets being the outer ends of cones which have their inner ends directed toward the centre of the eye. It is probable that the large, or compound, eyes of insects only serve to distinguish bright objects from dark objects. The simple eyes afford dis-

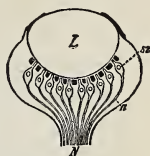


FIG. 134.—Diagram of simple eye of insect.

L, lens; N, optic nerve.

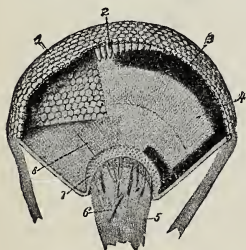


FIG. 135.—COMPOUND EYE OF INSECT.

1, hexagonal facets of crystalline cones. 6, blood vessel in optic nerve.

tinct images of objects within a few inches of the eye. In general, the sight of insects, contrary to what its complex sight organs would lead us to expect, is not at all keen. Yet an insect can fly through a forest without striking a twig or branch. Is it better for the eyes that are immovable in the head to be large or small? Which has comparatively larger eyes, an insect or a beast?

**Inherited Habit, or Instinct.**—Insects and other animals inherit from their parents their particular form of body and of organs which perform the different functions. For example, they inherit a nervous system with a structure similar to that of their parents, and hence with a tendency to repeat similar impulses and acts. Repeated acts constitute a habit, and *an inherited habit is called an in-*

*instinct.* Moths, for example, are used to finding nectar in the night-blooming flowers, most of which are white. The habit of going to white flowers is transmitted in the structure of the nervous system; so we say that moths have an instinct to go to white objects; it is sometimes more obscurely expressed by saying they are attracted or drawn thereby.

**Instincts are not Infallible.**—They are trustworthy in only one narrow set of conditions. Now that man makes many fires and lights at night, the instinct just mentioned often causes the death of the moth. The instinct to provide for offspring is necessary to the perpetuation of all but the simplest animals. The dirt dauber, or mud wasp, because of inherited habit, or instinct, makes the cell of the right size, lays the egg, and provides food for offspring that the mother will never see. It seals stung and semiparalyzed spiders in the cell with the egg. If you try the experiment of removing the food before the cell is closed, the insect will bring more spiders; if they are removed again, a third supply will be brought; but if taken out the third time, the mud wasp will usually close the cell without food, and when the egg hatches the grub will starve.

**The Development of Insects.**—The growth and the moulting of the grasshopper from egg to adult has been studied. All insects do not develop exactly by this plan. Some hatch from the egg in a condition markedly different from the adult. The butterfly's egg produces a wormlike caterpillar which has no resemblance to the butterfly. After it grows it forms an inclosing case in which it spends a quiet period of development and comes out a butterfly. This change from caterpillar to butterfly is called the *metamorphosis*. The life of an insect is divided into four



stages: (1) *egg*, (2) *larva*, (3) *pupa*, and (4) *imago*, or perfect insect (Figs. 136, 137, 138).

The egg stage is one of development, no nourishment being absorbed. The larval stage is one of voracious feeding and rapid growth. In the pupa stage no food is taken and there is no growth in size, but rapid development takes place. In the perfect stage food is eaten, but no growth in size takes place. In this stage the eggs are produced. When



FIG. 136. — Measuring worm, the larva of a moth.



FIG. 137. — Pupa of a mosquito.

there is very little resemblance between the larva and the imago, and no pupal stage, the metamorphosis, or change, is said to be *complete*. When, as with the grasshopper, no very marked change takes place between the larva and the imago, there being no pupal stage, the metamorphosis is said to be *incomplete*. By studying the illustrations and specimens, and by thinking of your past observations of insects, determine which of the insects in the following list have a complete metamorphosis: beetle, house-fly, grasshopper, butterfly, cricket, wasp.

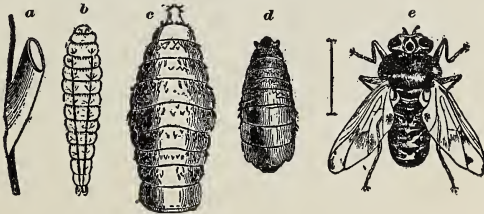


FIG. 138. — THE FOUR STAGES OF A BOTFLY, all enlarged.

*a*, egg on hair of horse (bitten off and swallowed); *b*, larva; *c*, larva with hooks for holding to lining of stomach; *d*, pupal stage, passed in the earth; *e*, adult horse fly.

## RECOGNITION-CHARACTERS FOR THE PRINCIPAL ORDERS OF ADULT WINGED INSECTS

(All are wingless when young, and wingless adult forms occur in all the orders: order *APTERA* lacks wing-bearing thoracic structures.)

A single pair of wings is characteristic of the order *DIPTERA*.

A jointed beak, that is sheath-like, inclosing the other mouth parts, is characteristic of the order *HEMIPTERA*.

A coiled sucking proboscis and a wing covering of dust-like microscopic scales are characteristic of the order *LEPIDOPTERA*.

Horny sheath-like fore wings, covering the hind wings and meeting in a straight line down the middle of the back, will distinguish the order *COLEOPTERA*.

Hind wings folded like a fan beneath the thickened and overlapping fore wings, will distinguish most members of the order *ORTHOPTERA*.

The possession of a sting (in females) and of two pairs of thin membranous wings — the small hind wing hooked to the rear margin of the fore wing — will distinguish the common *HYMENOPTERA*.

Besides these, there remain a number of groups most of which have in the past been included under the order *NEUROPTERA*, among which the May-flies will be readily recognized by the lack of mouth parts and by the possession of two or three long tails; the dragon-flies by the two pairs of large wings, enormous eyes, and minute bristle-like antennæ; the scorpion-flies, by the possession of a rigid beak, with the mouth parts at its tip; the caddis-flies, by their hairy wings and lack of jaws; the lace-wings, by the exquisite regularity of the series of cross veins about the margin of their wings, etc.



FIG. 139. — MAY-FLY. What order (see table)?



FIG. 140. — SILVER SCALE. (Order?)

**Exercise in the Use of the Table or Key.** — Write the name of the order after each of the following names of insects: —

- |                          |                                   |
|--------------------------|-----------------------------------|
| Wasp (Fig. 122)          | House-fly (Fig. 172)              |
| Weevil (Fig. 163)        | Flea (Fig. 173)                   |
| Squash bug (Fig. 184)    | Silver scale or earwig (Fig. 140) |
| Ant-lion (Fig. 170)      | Codling moth (Fig. 141)           |
| Dragon-fly (Fig. 177)    | Botfly (Fig. 138)                 |
| Ichneumon-fly (Fig. 159) |                                   |

**Moths and Butterflies.** — Order \_\_\_\_? Why \_\_\_\_ (p. 82)?

The presence of scales on the wings is a never-failing test of a moth or a butterfly. The wings do not fold at all. They are so large and the legs so weak and delicate that the butterfly keeps its balance with difficulty when walking in the wind.

The maxillæ are developed to form the long sucking proboscis. How do they fit together to form a tube? (See Fig. 147.) The proboscis varies from a fraction of an inch in the "miller" to five inches in some tropical moths, which use it to extract nectar from long tubular flowers. When not in use, it is held coiled like a watch spring under the head (Fig. 148). The upper lip (labrum), under lip (labium), and lip fingers (labial palpi) are very small, and the mandibles small or wanting (Fig. 146).

The metamorphosis is complete, the contrast between the caterpillar or larva of the moth and the butterfly and the adult form being very great. The caterpillar has the three pairs of jointed legs typical of insects; these are

found near the head (Fig. 141). It has also from three to five pairs of fleshy unjointed prolegs, one pair of which is always on the last segment. How many pairs of prolegs has the silkworm caterpillar? (Fig. 143.) The measuring worm, or looper? (Fig. 136.) The pupa has a thin shell. Can you see external signs of the antennæ, wings, and legs in this stage? (Fig. 143.) The pupa is concealed by protective coloration and is sometimes inclosed in a silken cocoon which was spun by the caterpillar before the last moult. Hairy caterpillars are uncomfortable for birds to eat. The naked and brightly marked ones (examples of warning coloration) often contain an acrid and distasteful fluid. The injuries from lepidoptera are done in the caterpillar stage. The codling moth (Fig. 141) destroys apples to the estimated value of \$6,000,000 annually. The clothes moth (Fig. 171) is a household pest. The tent caterpillar denudes trees of their leaves. The only useful caterpillar is the silkworm (Fig. 143). In Italy and Japan many of the country dwellings have silk rooms where thousands of these caterpillars are fed and tended by women and children. Why is the cabbage butterfly so called? Why can it not eat cabbage? Why does sealing clothes in a paper bag prevent the ravages of the clothes moth?

**Flight of Lepidoptera.** — Which appears to use more exertion to keep afloat, a bird or a butterfly? Explain why. Of all flying insects which would more probably be found highest up mountains? How does the butterfly suddenly change direction of flight? Does it usually fly in a straight or a zigzag course? Advantage of this? Bright colours are protective, as lepidoptera are in greatest danger when at rest on flowers. Are the brightest colours on upper or under side of wings of butterfly? Why? (Think of the

colours in a flower.) Why is it better for moths to hold their wings flat out when at rest? Where are moths during the day? How can you test whether the colour of the wings is given by the scales?

State how moths and butterflies differ in respect to: body, wings, feelers, habits.

**Insects and Flowers.** — Perhaps we are indebted to insects for the bright colours and sweet honey of flowers. Flowers need insects to carry their pollen to other flowers, as cross-fertilization produces the best seeds. The insects need the nectar of the flowers for food, and the bright colours and sweet odours are the advertisements of the flowers to attract insects. Flowers of brightest hues are the ones that receive the visits of insects. Moths, butterflies, and bees carry most pollen (see *Beginners' Botany*, Chap. XIX).

**Comparative Study.** — Make a table like this, occupying entire page of notebook, leaving no margins, and fill in accurately: —

	GRASS- HOPPER	BUTTER- FLY	FLY pp. 92, 93	DRAGON- FLY, p. 93	BEETLE pp. 90, 91	BEE pp. 88, 89
Number and kind of wings						
Description of legs						
Antennæ (length, shape, joints)						
Biting or sucking mouth parts						
Complete or incom- plete metamor- phosis						

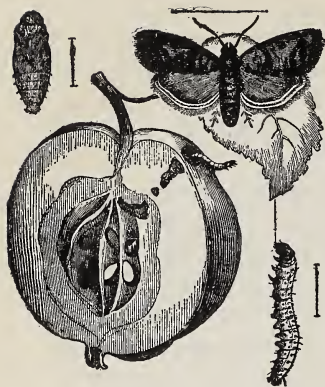


FIG. 141. — CODLING MOTH, from egg to adult. (See Farmers' Bulletin, p. 95.)

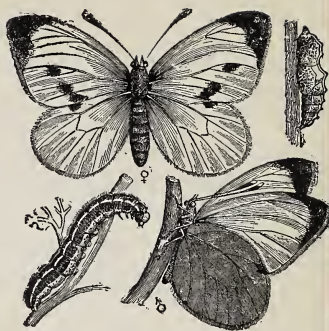


FIG. 142. — CABBAGE BUTTERFLY, male and female, larva and pupa.



FIG. 143. — LIFE HISTORY OF SILKWORM.



FIG. 144. — SCALES FROM BUTTERFLIES' WINGS, as seen under microscope.



TO THE TEACHER: *These illustrated studies require slower and more careful study than the text. One, or at most two, studies will suffice for a lesson. The questions can be answered by studying the figures.*

FIGS. 141-148. Illustrated Study of Lepidoptera.— Study the stages in the development of *codling moth*, *silk-worm moth*, and *cabbage butterfly*.

Where does each lay its eggs? What does the larva of each feed upon? Describe the pupa of each. Describe the adult forms. Find the *spiracles* and *prolegs* on the silkworm. Compare *antennæ* of moth and butterfly. Which has larger body compared to size of wings?

Describe the *scales* from a butterfly's wings as seen under microscope (144). How are the scales arranged on moth's wing (145)? By what part is scale attached to wing? Do the scales overlap?

Study butterfly's head and *proboscis* (Figs. 146-148). What shape is compound eye? Are the antennæ jointed? Is the proboscis jointed? Why not call it a tongue? (See text.)

Which mouth parts have almost disappeared? What is the shape of cut ends of halves of proboscis? How are the halves joined to form a tube?

If you saw a butterfly on a flower, for what purpose would you think it was there? What, if you saw it on a leaf? How many spots on fore wing of female cabbage butterfly? (Fig. 124, above.)

Does the silkworm chrysalis fill its cocoon?



FIG. 145.—SCALES ON MOTH'S WING.



FIG. 146.—HEAD OF BUTTERFLY.

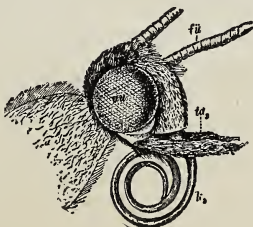


FIG. 148.—HEAD OF BUTTERFLY (side view).



FIG. 147.—SECTION OF PROBOSCIS of butterfly showing lapping joint and dovetail joint.

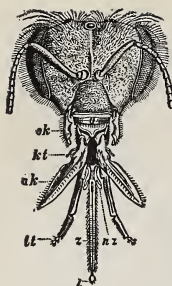


FIG. 149.



FIG. 150.



FIG. 151.

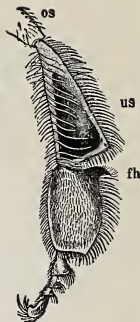


FIG. 152.



FIG. 153.



FIG. 154.



FIG. 155.



FIG. 156.



FIG. 157.

FIGS. 149-161. Illustrated Study of Bees and their Kindred. — Head of worker (Fig. 149): *o*, upper lip; *ok*, chewing jaws; *uk*, grasping jaws; *kt*, jaw finger; *lt*, lip finger; *z*, tongue.

How do heads of drone (150) and queen (151) differ as to mouth, size of the two compound eyes, size and position of the three simple eyes? Is the head of a worker more like head of drone or head of queen? Judging by the head, which is the queen, drone, and worker in Figs. 154-156? Which of the three is largest? Smallest? Broadest?

Figure 152 shows hind leg of worker. What surrounds the hollow, *us*, which serves as pollen basket? The point, *fh*, is a tool for removing wax which is secreted (*c*, Fig. 157) between rings on abdomen. In Fig. 158, find relative positions of heart, *v*, food tube, and nerve chain. Is crop, *J*, in thorax or abdomen? In this nectar is changed to honey, that it may not spoil. Compare nerve chain in Fig. 132.

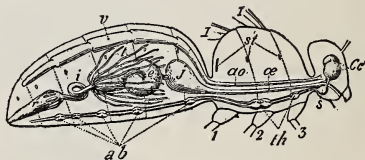


FIG. 158. — Anatomy of bee.

Compare the cells of *bumble-bee* (Fig. 153) with those of *hive-bee*. They differ not only in shape but in material, being made of web instead of wax, and they usually contain larvæ instead of honey. Only a few of the queens among *bumble-bees* and wasps survive the winter. How do ants and honey bees provide for the workers also to survive the winter? Name all the social insects that you can think of. Do they all belong to the same order?

The *ichneumon-fly* shown enlarged in Fig. 159 lays its eggs under a caterpillar's skin. What becomes of the eggs? The true size of the insect is shown by the cross lines at *a*. The eggs are almost microscopic in size. The pupæ shown (true size) on caterpillar are sometimes mistaken for eggs. The same mistake is made about the pupa cases of ants. *Ichneumon-flies* also use tree-borers as "hosts" for their eggs and larva. Is this insect a friend of man?

The *digging wasp* (Figs. 160 and 161) supplies its larva with caterpillars and closes the hole, sometimes using a stone as pounding tool. Among the few other uses of tools among lower animals are the elephant's use of a branch for a fly brush, and the ape's use of a walking stick. This wasp digs with fore feet like a dog and kicks the dirt out of the way with its hind feet.

Are the wings of bees and wasps more closely or less closely veined than the wings of dragon-flies? (Fig. 177.)

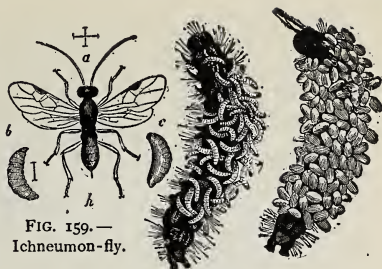


FIG. 159.—  
*Ichneumon-fly*.



FIG.  
160.

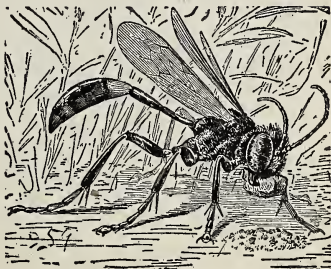


FIG. 161.—Wasp using pebble.  
From Peckham's "Solitary Wasps,"  
Houghton, Mifflin & Co.

FIG. 162. — Diving beetle (*Dytiscus*), with larva, *a*.

Illustrated  
Study of  
Beetles.



FIG. 163. — Weevil.



FIG. 164.



FIG. 165.



FIG. 166. — Click beetle.



FIG. 167. — MAY BEETLE.



FIG. 168.



FIG. 169. — Colorado beetle (potato bug).



**Illustrated Study of Beetles (Figs. 162-169).**—Write the life history of the *Colorado beetle*, or potato bug (Fig. 169), stating where the eggs are laid and describing the form and activities of each stage (the pupal stage, *b*, is passed in the ground).

Do the same for the *May beetle* (Figs. 167-168). (It is a larva—the white grub—for three years; hogs root them up.) Beetles, like moths, may be trapped with a lantern set above a tub of water.

Where does a *Scarab* (or sacred beetle of the Egyptians), also called tumble bug (Fig. 164), lay its eggs (Fig. 165)? Why?

How does the *click beetle*, or jack snapper (Fig. 166), throw itself into the air? For what purpose?

The large proboscis of the *weevil* (Fig. 163) is used for piercing a hole in which an egg is laid in grain of corn, boll of cotton, acorn, chestnut, plum, etc.

How are the legs and body of the *diving beetle* suited for swimming (Fig. 162)? Describe its larva.

What is the shape of the lady bug (Fig. 97)? It feeds upon plant lice (Fig. 185). Is any beetle of benefit to man?

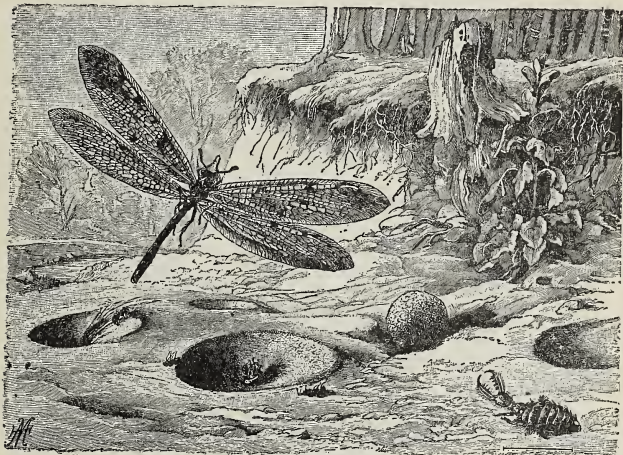


FIG. 170. — Life history of ant-lion.

**Illustrated Study of Ant-lion, or Doodle-Bug (Fig. 170).**—Find the pit-fall (what shape?); the larva (describe it); the pupa case (ball covered with web and sand); the imago. Compare imago with dragon-fly (Fig. 177).

How does ant-lion prevent ant from climbing out of pit-fall (see Fig. 170)? What is on edge of nearest pit-fall? Explain.

Ant-lions may be kept in a box half filled with sand and fed on ants. How is the pit-fall dug? What part of ant is eaten? How is unused food removed?

How long is it in the larval state? Pupal state? Keep net over box to prevent adult from flying away when it emerges.



FIG. 171.

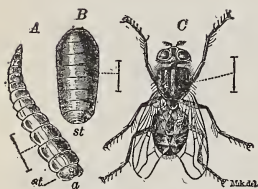


FIG. 172. — Metamorphosis of house-fly (enlarged).



FIG. 174. — Louse and its eggs attached to a hair. Natural size and magnified.

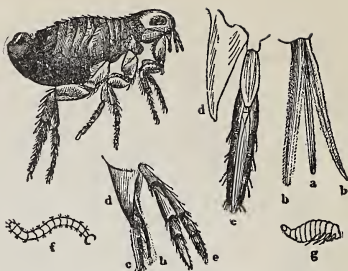
FIG. 175. — Bed bug.  $\times 5$ .

FIG. 173. — Metamorphosis of flea.

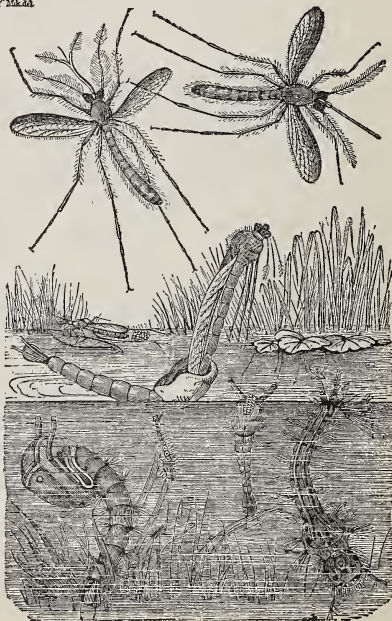


FIG. 176. — Life history of mosquito.



**Illustrated Study of Insect Pests (Figs. 171-176).**— Why does the *clothes moth* (171) lay its eggs upon woollen clothing? How does the larva conceal itself? The larva can cut through paper and cotton, yet sealing clothes in bags of paper or cotton protects them. Explain.

The *house-fly* eats liquid sweets. It lays its eggs in horse dung. Describe its larval and pupal forms. Banishing horses from city would have what beneficial effect?

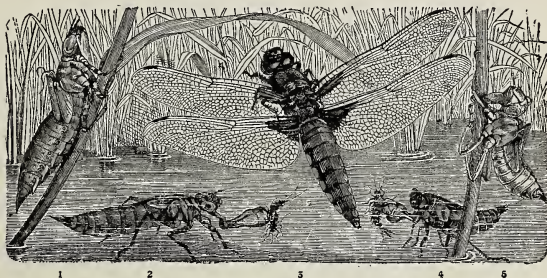
Describe the *louse* and its eggs, which are shown attached to a hair, natural size and enlarged.

Describe the *bed bug*. Benzine poured in cracks kills bed bugs. Do bed bugs bite or suck? Why are they wingless?

Describe the larva, *f*, pupa, *g*, and the adult *flea*, all shown enlarged. Its mandibles, *b, b*, are used for piercing. To kill fleas lather dog or cat completely and let lather remain on five minutes before washing. Eggs are laid and first stages passed in the ground.

How does the *mosquito* lay its eggs in the water without drowning (176)? Why are the eggs always laid in still water? Which part of the larva (wiggletail) is held to the surface in breathing? What part of the pupa (called tumbler, or bull head) is held to the surface in breathing? Give differences in larva and pupa. Where does pupa change to perfect insect? Describe mouth parts of male mosquito (at left) and female (at right). Only female mosquitoes suck blood. Males suck juice of plants. Malarial mosquito alights with hind end of body raised at an angle. Why does killing fish and frogs increase mosquitoes? 1 oz. of kerosene for 15 ft. of surface of water, renewed monthly, prevents mosquitoes.

What is the use to the squash bug (Fig. 184) of having so bad an odour?



**FIG. 177. Illustrated Study of Dragon-fly.**— 3 shows dragon fly laying its eggs in water while poised on wing. Describe the larval form (water tiger). The extensible tongs are the maxillæ enlarged. The pupa (1) is active and lives in water. Where does transformation to adult take place (5)? Why are eyes of adult large? its legs small? Compare front and hind wings.

Do the eyes touch each other? Why is a long abdomen useful in flight? Why would long feelers be useless? What is the time of greatest danger in the development of the dragon-fly? What other appropriate name has this insect? Why should we never kill a dragon-fly?



FIG. 178. — The tarantula.



FIG. 179. — Trap-door spider.



FIG. 180.

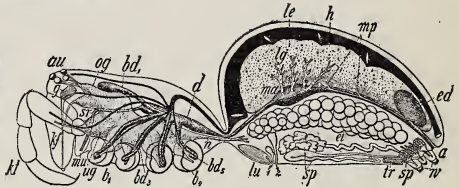


FIG. 181. — Anatomy of spider.

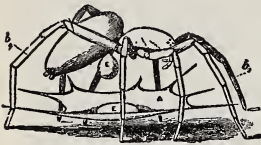


FIG. 182. — Laying egg.

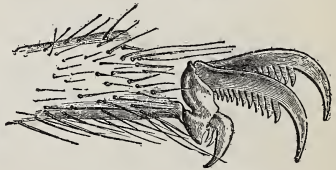


FIG. 183. — Foot of spider.

**Illustrated Study of Spiders** (Figs. 178-183). — The tarantula, like most spiders, has eight simple eyes (none compound). Find them (Fig. 178). How do spiders and insects differ in body? Number of legs? Which have more joints to legs? Does trap-door spider hold the door closed (Fig. 179)? How many pairs of spinnerets for spinning web has a spider (*Spw*, 180)? Foot of spider has how many claws? How many combs on claws for holding web? Spiders spin a cocoon for holding eggs. From what part of abdomen are eggs laid (*E*, 182; 2, 181)? Find spider's air sacs, *lu*, Fig. 181; spinning organs, *sp*; fang, *kt*; poison gland, *g*; palpi, *kt*; eyes, *au*; nerve ganglia, *og*, *ug*; sucking tube, *sr*; stomach, *d*; intestine, *ma*; liver, *le*; heart, *h*, (black); vent, *a*. Give two reasons why a spider is not an insect. How does it place its feet at each step (Fig. 110)? (Does the size of its nerve ganglia indicate great or little intelligence? Why do you think first part of body corresponds to both head and thorax of insects?)

The following Farmer's Bulletins, (revised to 1921) are available for distribution to those interested, by the United States Department of Agriculture, Washington, D.C.—

Farmer's Bulletin No. 47, Insects Affecting the Cotton Plant; No. 447, Bee Keeping; No. 440, The Peach Twig Borer; No. 120, The Principal Insects Affecting the Tobacco Plant; No. 856, Important Insecticides; No. 835, The Principal Insect Enemies of Growing Wheat; No. 799, Carbon Bisulphide as an Insecticide; No. 243, Insecticides and Fungicides; No. 15? (revised) Mange in Cattle; No. 155, How Insects Affect Health in Rural Districts; No. 492, The Control of the Codling Moth; No. 172, Scale Insects and Mites on Citrus Trees; No. 196, Usefulness of the Toad; No. 209, Controlling the Boll Weevil in Cotton Seed and at Ginneries; No. 211, The Use of Paris Green in Controlling the Cotton Boll Weevil; No. 872, The Cotton Bollworm; No. 848, The Control of the Boll Weevil; No. 223, Miscellaneous Cotton Insects in Texas; No. 908, The Control of the Codling Moth and Apple Scab.

Bulletins of the Bureau of Entomology may be obtained from the same source, while the supply lasts, as follows:

Destructive Locusts; The Honey Bee; The San José Scale; The Principal Household Insects of the United States; The Gypsy Moth in America; The Periodical Cicada; The Chinch Bug; The Hessian Fly; Insects Injurious to Vegetables; Notes on Mosquitoes; Some Insects Attacking the Stems of Growing Wheat, Rye, Barley, and Oats.

Bulletins on Similar Topics, Published by the Department of Agriculture, Ontario—

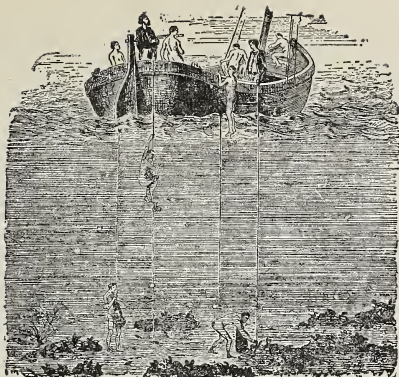
(Write to the Publications Branch)

- Bulletin No. 187—The Codling Moth
- Bulletin No. 195—The Insecticides and Fungicides
- Bulletin No. 198—Lime Sulphur Wash
- Bulletin No. 219—The San José and Oyster-shell Scales
- Bulletin No. 241—Peach Growing in Ontario
- Bulletin No. 250—Insects Attacking Fruit Trees
- Bulletin No. 251—Insects Affecting Vegetables
- Bulletin No. 256—The Wintering of Bees
- Bulletin No. 257—The More Important Fruit Tree Diseases in Ontario
- Bulletin No. 258—The More Important Fungus and Bacterial Diseases of Vegetables in Ontario
- Bulletin No. 271—The Apple Maggot
- Bulletin No. 276—Bee Diseases in Ontario

Bulletins Published by the Department of Agriculture, Ottawa—

(Write to the Publications Branch)

- Bulletin No. 9—The Army Worm
- Bulletin No. 10—Cutworms and their Control
- Bulletin No. 26—Bees and How to Keep Them
- Circular No. 9—1921—Common Garden Insects and their Control



Pearl divers.

## CHAPTER IX

### *MOLLUSCS*

#### THE FRESH-WATER MUSSEL

**SUGGESTIONS.** — The mussel is usually easy to procure from streams and lakes by raking or dredging. In cities the hard-shelled clam, or quahog, is for sale at the markets, and the following descriptions apply to the anodon, unio, or quahog, with slight changes in regard to the siphons. Mussels can be kept alive for a long time in a tub with sand in the bottom. Pairs of shells should be at hand for study.

**External Features.** — The shell is an elongated oval, broader and blunter at one end (Fig. 188). Why does the animal close its shell? Does it open the shell? Why? Does it thrust the foot forward and pull up to it, or thrust the foot back and push? (Mussels and clams have no bones.) Does it go with the blunt end or the more tapering end of the shell forward? (Fig. 188.) Can a mussel swim? Why, or why not?

Lay the shells, fitted together, in your hand with *the hinge side away from you and the blunt end to the left* (Fig. 188).

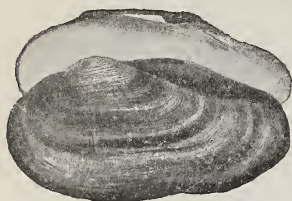


FIG. 188. — ANODON, or fresh-water mussel.

Is the right or the left shell uppermost? Which is the top, or dorsal, side? Which is the front, or anterior, end? Is the straight edge at the top or at the bottom? Our word "valve" is derived from a word meaning shell, because the Romans used

shells for valves in pumps. Is the mussel a univalve or a bivalve? Which kind is the oyster? The snail?

Does the mussel have *bilateral symmetry*? Can you find a *horny covering*, or epidermis, over the limy shell of a fresh specimen? Why is it necessary? Does water dissolve lime? Horn? Find a bare spot. Does any of the shell appear to be missing there?

The bare projection on each shell is called the *umbo*. Is the umbo near the ventral or the dorsal line? The posterior or anterior end? Is the surface of the *umbones* worn? Do the umbones rub against the sand as the mussel ploughs its way along? How are the shells held together? Where is the *ligament* attached? (Fig. 189.) Is it opposite the umbones or more to the front or to the rear? Fig. 189.) Is the ligament of the same material as the shell? Is the ligament in a compressed condition when the shell is open or when it is closed? (Fig. 189.) When is the muscle relaxed?

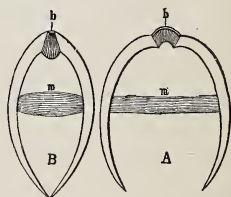


FIG. 189. — DIAGRAM OF SHELL open and closed, showing muscle, *m*, and ligament, *b*.



Notice the *lines* on the outside of the shell (Figs. 188 and 190). What point do they surround? They are *lines of growth*. Was each line once the margin of the shell? If the shell should increase in size, what would the present margin become? (Fig. 191.) Does growth take place on the margin only? Did the shell grow thicker as it grew larger? Where is it thinnest?

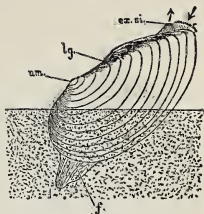


FIG. 190. — MUSSEL crawling in sand.

**Draw** the outside of the shell from the side. Draw a dorsal view. Near the drawings write the names of the margins of the shell (p. 98) and of other parts learned, using lines to indicate the location of the parts.

Study the surface of the shell inside and out. The inside is called *mother-of-pearl*. Is it of lime? Is the deeper layer of the shell of lime? (When weak hydrochloric acid or strong vinegar is dropped on limy substances, a gas, carbon dioxide, bubbles up.) Compare the thickness of the *epidermal layer*, the middle *chalky layer*, and the inner, *pearly layer*.

**Anatomy of the Mussel.**—What parts protrude at any time beyond the edge of the shell? (Fig. 190.) The shell is secreted by two folds of the outer layer of the soft body of the mussel. These large, flaplike folds hang down on each side, and are called the *mantle*. The two great flaps of the mantle hang down lower than the rest of the body and line the shell which it secretes (Fig. 192).

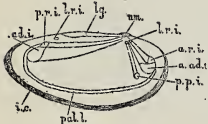


FIG. 191. — DIAGRAM. Change of points of attachment of muscles as mussel enlarges. (Morgan.)

The epidermis of the mantle secretes the shell just as the epidermis of the crayfish secretes its crust. Can you find

the pallial line, or the line to which the mantle extended on each shell when the animal was alive? A free portion of the mantle extended like a fringe below the pallial line.

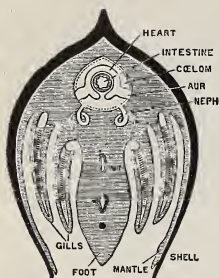


FIG. 192.—CROSS SECTION OF MUSSEL. (Diagram, after Parker.)

The shells were held together by two large *adductor muscles*. The anterior adductor (Fig. 193) is near the front end, above the foot. The posterior adductor is toward the rear end, but not so near the end as the anterior. Can you find both *muscle scars* in the shells? Are they nearer the ventral or the dorsal surface? The points of attachment travelled downward and farther apart as the animal grew (see Fig. 191). Higher

than the larger scars are small scars, or impressions, where the protractor and retractor muscles that extend and draw in the foot were attached.

The muscular *foot* extends downward in the middle, halfway between the shells (Fig. 193). On each side of the foot and behind it hang down the two pairs of gills, the outer pair and the inner pair (Fig. 192). They may be compared to four V-shaped troughs with their sides full of holes. The water enters the troughs through the holes and overflows above. Is there a marked difference in the size of the two pairs of gills? A kind of

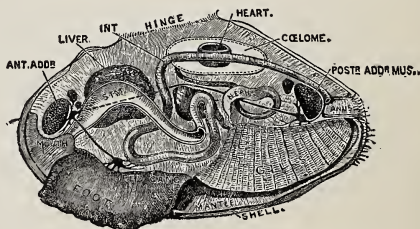


FIG. 193.—ANATOMY OF MUSSEL. (Beddard.)

chamber for the gills is made by the joining of the mantle flaps below, along the ventral line. The mantle edges are separated at two places, leaving openings called *exhalent* and *inhalent siphons*.

Fresh water with its oxygen, propelled by *cilia* at the opening and on the gills, enters through the lower or inhalent siphon, passes between the gills, and goes to an upper passage, leaving the gill chamber by a slit which separates the gills from the foot. For this passage, see arrow (Fig. 194). The movement of the water is opposite to the way the arrow points. After going upward and backward, the water emerges by the exhalent siphon. The gills originally consisted of a great number of filaments. These are now united, but not completely so, and the gills still have a perforated or lattice structure. Thus they present a large surface for absorbing oxygen from the water.

The **mouth** is in front of the foot, between it and the anterior adductor muscle (Fig. 194). On each side of the mouth are the *labial palps*, which are lateral lips (Fig. 195). They have cilia which convey the food to the mouth after the inhalent siphon has sent food beyond the gill chamber and near to the mouth. Thus both food and oxygen enter at the inhalent siphon. The foot is in the position of a lower lip, and if regarded as a greatly extended lower lip, the animal may be said to have what is to us the absurd habit of using its lower lip as a foot. The foot is some-

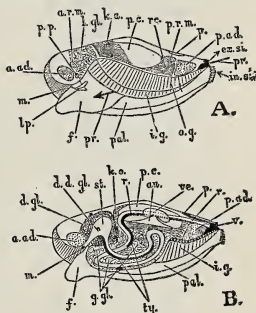


FIG. 194. — MUSSEL.

A, left shell and mantle flap removed.

B, section through body.

Question: Guided by other figures, identify the parts to which lines are drawn.

times said to be hatchet-shaped (Fig. 195). Do you see any resemblance? Does the foot penetrate deep or shallow into the sand? (Fig. 190.) Why, or why not?

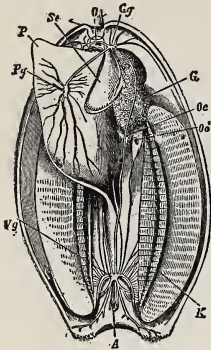


FIG. 195.—MUSSEL. From below. Level cut across both shells.

*Se*, palp; *P*, foot; *O*, mouth; *G*, liver; *Gg*, *Vg*, *Pg*, gasteria.

and into the gill chamber below (*Neph.*, Fig. 193). The tubes are surrounded by numerous blood-vessels (Fig. 198) and carry off the waste matter from the blood.

The **nervous system** consists of *three pairs of ganglia* and nerves (Fig. 197). The ganglia are distinguishable because of their orange colour. The pedal ganglia on the front of the foot are easily seen also; the visceral ganglia on the posterior adductor muscle may be seen without removing the mussel from the shell (Fig. 193). The reproductive organs



FIG. 197.

open into the rear portion of the gill cavity (Fig. 193). The sperms, having been set free in the water, are drawn into the ova by the same current that brings the food. The eggs

The food tube of the mussel is comparatively simple. Behind the mouth it enlarges into a swelling called the *stomach* (Fig. 193). The bile ducts of the neighbouring liver empty into the stomach. The *intestine* makes several turns in the substance of the upper part of the foot and then passing upward, it runs approximately straight to the vent (or anus), which is in the wall of the exhalant siphon. The intestine not only runs through the *pericardial cavity* (celome) surrounding the heart, but through the ventricle of the heart itself (Fig. 196).

The **kidneys** consist of tubes which open into the pericardial chamber above

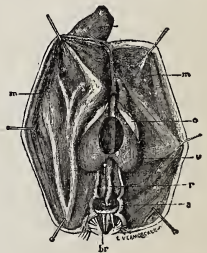


FIG. 196.—HEART OF MUSSEL, with intestine passing through it.

are hatched in the gills. After a while the young mussels go out through the siphon.

**Summary.**—In the gills (Fig. 198) the blood gains what? Loses what? From the digestive tube the blood absorbs nourishment. In the kidneys the blood is partly purified by the loss of nitrogenous waste.

The cilia of the fringes on the inhalent, or lower, siphon, vibrate continually and drive water and food particles into the mouth cavity. Food particles that are brought near the labial palps are conveyed by them to the mouth. As the water passes along the perforated gills, its oxygen is absorbed; the mantle also absorbs oxygen from the water as it passes. The water, as stated before, goes next through a passage between the foot and the palp into the cavity above the gills and on out through the exhalent siphon. By stirring the water, or placing a drop of ink near the siphons of a mussel kept in a tub, the direction of its flow may be seen. The pulsations of the heart are plainly visible in a living mollusc.

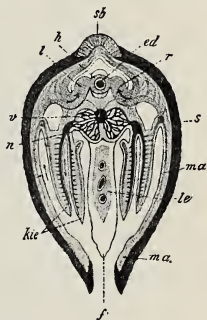


FIG. 198. — DIAGRAM OF MUSSEL CUT ACROSS, showing mantle, *ma*; gills, *kie*; foot, *f*; heart, *h*; intestine, *ed*.

**Habits of the Mussel.**—Is it abundant in clear or in muddy water; swift, still, or slightly moving water? Describe its track or furrow. What is its rate of travel? Can you distinguish the spots where the foot was attached to the ground? How long is one “step” compared to the length of the shell? The animal usually has the valves opened that it may breathe and eat. The hinge ligament acts like the case spring of a watch, and holds the valves open unless the adductor muscles draw them together (Fig. 189).



When the mussel first hatches from the egg, it has a triangular shell. It soon attaches itself to some fish and thus travels about. After two months it drops to the bottom again.

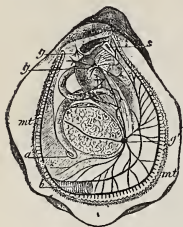


FIG. 199.—OYSTER.

C, mouth; a, vent; g, g', ganglia; mt, mantle; b, gill.

**Other Mollusca.** — The *oyster's* shells are not an exact pair, the shell which lies upon the bottom being hollowed out to contain the body, and the upper shell being flat. Can you tell by examining an oyster shell which was the lower valve? Does it show signs of having been attached to the bottom? The young oyster, like the young mussel, is free-swimming. Like the arthropoda, most molluscs undergo a metamorphosis to reach the adult stage (Fig. 199).

Examine the shells of clams, snails, scallops, and cockles. Make drawings of their shells. The slug is very similar to the snail except that it has no shell. If the shell of the snail shown in Fig. 202 were removed, there would be left a very good representation of a slug.



FIG. 200.—TROCHUS.



FIG. 201.—CYPRÆA. (Univalve, with a long opening to shell.)

**Economic Importance of Mollusca.** — Several species of clams are eaten. One of them is the *hard-shell clam* (quahog) found on the Atlantic coast from Cape Cod to Texas. Its shell is white. It often burrows slightly beneath the surface. The *soft-shell clam* is better liked as food. It lives along the shores of all northern seas. It burrows a foot beneath the surface and extends its siphons



through the burrow to the surface when the tide is in, and draws into its shell the water containing animalcules and oxygen.

*Oysters* to the value of many millions of dollars are gathered and sold every year. The most valuable oyster fisheries of North America are in Chesapeake Bay. The young oysters, or "spat," after they attach themselves to the bottom in shallow water, are transplanted. New oyster beds are formed in this way. The beds are sometimes strewn with pieces of rock, broken pottery, etc., to encourage the oysters to attach themselves. The dark spot in the fleshy body of the oyster is the digestive gland, or liver. The cut ends of the tough adductor muscles are noticeable in raw oysters. The starfish is very destructive in oyster beds.

*Pearls* are deposited by bivalves around some irritating particle that gets between the shell and the mantle. The pearl oyster furnishes most of the pearls; sometimes pearls of great value are obtained from fresh-water mussels. Name articles that are made partly or wholly of mother-of-pearl.

**Study of a Live Snail or Slug.** — Is its body dry or moist? Do land

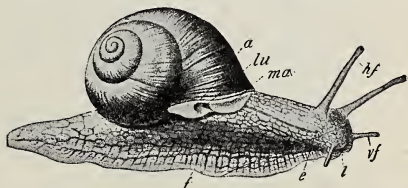


FIG. 202. — A SNAIL.

*l*, mouth; *vf*, *hf*, feelers; *e*, opening of egg duct; *f*, foot; *ma*, mantle; *lu*, opening to lung; *a*, vent.

snails and slugs have lungs or gills? Why? How many pairs of tentacles have they? What is their relative length and position? The eyes are dark spots at bases of tentacles of snail and at the tips of the rear tentacles of slug. Touch the tentacles. What happens? Do the tentacles simply stretch, or do they turn inside

out as they are extended? Is the respiratory opening on the right or the left side of the body? On the mantle fold or on the body?



FIG. 203. — A SLUG.

(Figs. 202-3-4.) How often does the aperture open and close?

Place the snail in a moist tumbler. Does

the whole under surface seem to be used in creeping? Does the creeping surface change shape as the snail creeps? Do any folds or wrinkles seem to move either toward the front or the rear of its body? Is enough mucus left to mark the path travelled? The fold moves to the front, adheres, and smooths out as the slug or snail is pulled forward.

**Cephalopods.** — The highest and best developed molluscs are the **cephalopods**, or “head-footed” molluscs. Surrounding the mouth are eight or ten appendages which serve both as feet and as arms. These appendages have two rows of sucking disks by which the animal attaches itself to the sea bottom, or seizes fish or other prey with a firm grip. The commonest examples are the

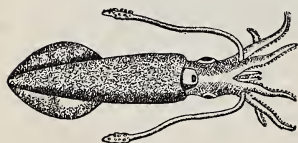


FIG. 205. — A SQUID.



FIG. 204. — CIRCULATION AND RESPIRATION IN SNAIL.

*a*, mouth; *b*, *b*, foot; *c*, vent; *d*, *d*, lung; *h*, heart. Blood vessels are black. (Perrier.)

*squid*, with a long body and ten arms, and the *octopus*, or devil-fish, with a short body and eight arms. Cephalopods have strong biting mouth parts and complex eyes somewhat resembling the eyes of backboneed, or vertebrate, animals. The

large and staring eyes add to the uncanny, terrifying appearance.

The sepia or “ink” discharged through the siphon of the squid makes a dark cloud in the water and favours its escape from

enemies almost as much as does its swiftness (Fig. 205). The squid sometimes approaches a fish with motion so slow as to be imperceptible, and then suddenly seizes it, and quickly kills it by biting it on the back behind the head.

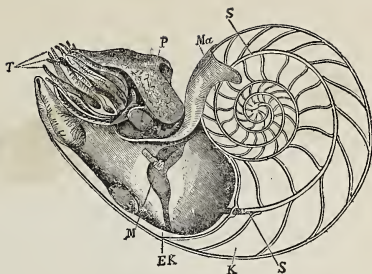


FIG. 206. — PEARLY NAUTILUS. (Shell sawed through to show chambers used when it was smaller, and siphuncle, *S*, connecting them. Tentacles, *T*.)

The octopus is more sluggish than the squid. Large species called devilfish sometimes have a spread of arms of twenty-five feet. The *pearly nautilus* (Fig. 206) and the *female of the paper argonaut* (Fig. 207) are examples of cephalopods that have shells. The *cuttlefish* is closely related to the squid.

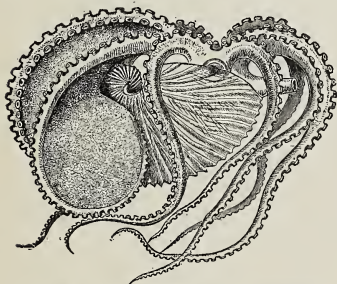


FIG. 207. — PAPER ARGONAUT (female).  $\times \frac{1}{3}$  (i.e. the animal is three times as long and broad as figure).



FIG. 208. — PAPER ARGONAUT (male).  $\times \frac{1}{2}$ .

**General Questions.** — The living parts of the mussel are very soft, the name mollusca being derived from the Latin word *mollis*, soft. Why is it that the softest animals, the molluscs, have the hardest coverings?

To which class of molluscs is the name acephala (headless) appropriate? Lamellibranchiata (platelike gills)?

Why is a smooth shell suited to a clam and a rough shell suited to an oyster? Why are the turns of a snail's shell so small near the centre?

Why does the mussel have no use for head, eyes, or projecting feelers? In what position of the valves of a mussel is the hinge ligament in a stretched condition? How does the shape of the mussel's gills insure that the water current and the blood current are brought in close contact?

The three main classes of molluscs are: the pelecypoda (hatchet-footed); gastropoda (stomach-footed); and cephalopoda (head-footed). Give an example of each class.

### Comparison of Molluscs

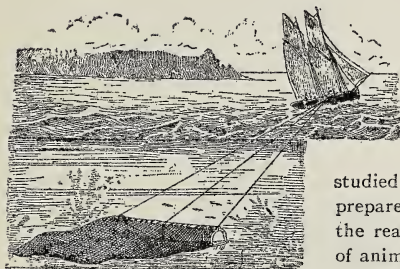
	MUSSEL	SNAIL	SQUID
Shell			
Head			
Body			
Foot			
Gills			
Eyes			

### Comparative Review.—(To occupy an entire page in notebook.)

	GRASS-HOPPER	SPIDER	CRAYFISH	CENTIPEDE	MUSSEL
Bilateral or radiate					
Appendages for locomotion					
Names of divisions of body					
Organs and method of breathing					
Locomotion					

## CHAPTER X

### FISHES



#### SUGGESTIONS. —

The behaviour of a live fish in clear water, preferably in a glass vessel or an aquarium, should be studied. A skeleton may be prepared by placing a fish in the reach of ants. Skeletons of animals placed on ant beds are cleaned very thoroughly.

The study of the perch, that follows, will apply to almost any other common fish.

**Movements and External Features.** — What is the *general shape of the body* of a fish? How does the dorsal, or upper, region differ in form from the ventral? Is there a narrow part or neck where the head joins the trunk? Where is the body thickest? What is the ratio between the length and the height? (Fig. 209.) Are the right and the left sides alike? Is the symmetry of the fish bilateral or radial?

The *body of the fish may be divided* into three regions—the head, the trunk, and the tail. The trunk begins with the foremost scales; the tail is said to begin at the vent, or anus. Which regions bear appendages? Is the head movable independently of the trunk, or do they move together? State the advantage or the disadvantage in this. Is the body depressed (flattened vertically) or compressed

(flattened laterally)? Do both forms occur among fishes? (See figures on pages 123, 124.)

How is the *shape of the body advantageous for movement*? Can a fish turn more readily from side to side, or up and down? Why? Is the head wedge-shaped or conical? Are the jaws flattened laterally or vertically? The fish swims in the water, the bird swims in the air. Account for the differences in the shape of their bodies.

Is the *covering of the body* like the covering of any animal yet studied? The scales are attached in little pockets,

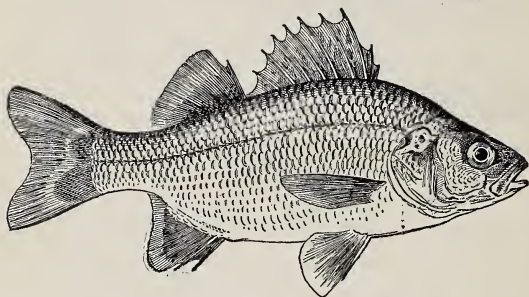


FIG. 209. — WHITE PERCH (*Morone Americana*).

or folds, in the skin. Observe the shape and size of scales on different parts of the body. What parts of the fish are without scales? Examine a single scale; what is its shape? Do you see concentric lines of growth on a scale? Sketch a few of the scales to show their arrangement. What is the use of scales? Why are no scales needed on the head? How much of each scale is hidden? Is there a film over the scale? Are the colours in the scale or on it?

**The Fins.** — Are the movements of the fish active or sluggish? Can it remain stationary without using its fins?



Can it move backward? How are the fins set in motion? What is the colour of the flesh, or muscles, of a fish? Count the fins. How many are in pairs? (Fig. 209.) How many are vertical? How many are on the side? How many are on the middle line? Are the paired or the unpaired fins more effective in balancing the fish? In turning it from side to side? In raising and lowering the fish? In propelling it forward? How are some of the fins useful to the fish besides for balancing and swimming?

The hard *spines* supporting the fins are called the fin rays. The fin on the dorsal line of the fish is called the *dorsal* fin. Are its rays larger or smaller than the rays of the other fins? The perch is sometimes said to have two dorsal fins, since it is divided into two parts. The fin forming the tail is called the tail fin, or *caudal* fin. Are its upper and its lower corners alike in all fishes? (Fig. 228.) On the ventral side, just behind the vent, is the ventral fin, also called the anal fin. The three fins mentioned are unpaired fins. Of the four-paired fins, the pair higher on the sides (and usually nearer the front) are the *pectoral* fins. The pair nearer the ventral line are the *pelvic* fins. They are close together, and in many fish are joined across the ventral line. The ventral fins are compared to the legs, and the pectoral fins to the arms, of higher vertebrates. (Fig. 244.) Compare fins of fish, pages 123, 124.

Make a **drawing** of the fish seen from the side, omitting the scales unless your drawing is very large.

Are the **eyes** on the top or on the sides of the head, or on both? Can a fish shut its eyes? Why, or why not? Is the eyeball bare, or covered by a membrane? Is the covering of the eyeball continuous with the skin of the head? Is there a fold or wrinkle in this membrane or the surrounding skin? Has the eye a pupil? An iris? Is the eye of

the fish immovable, slightly movable, or freely movable? Can it look with both eyes at the same object? Is the *range of vision* more upward or downward? To the front

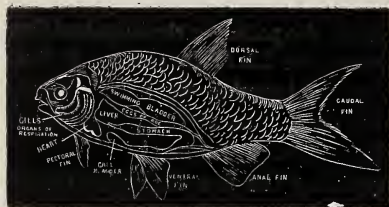


FIG. 210.—BLACKBOARD OUTLINE OF FISH.

or the side? In what direction is vision impossible? Can a fish close its eyes in sleep? Does the eyeball appear spherical or flattened in front? The ball is really spherical, the lens is very convex, and fish are nearsighted. Far sight would be useless in a dense medium like water. In what direction from the eyes are the nostrils (Fig. 211)? There are two pair of nostrils, but there is only one pair of nasal cavities, with two nostrils opening into each. There are no nasal passages to the mouth, as the test with a probe shows that the cavities do not open into the mouth. What two functions has the nose in man? What function has it in the fish?

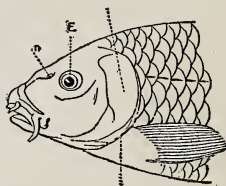


FIG. 211.—HEAD OF CARP.

There are *no external ears*. The ear sacs are embedded in the bones of the skull. Is hearing acute or dull? When you are fishing, is it more necessary not to talk or to step lightly, so as not to jar the boat or bank?

What is the use of the large openings found at the back of the head on each side? (Fig. 211.) Under the skin at the sides of the head are thin membrane bones formed from the skin; they aid the skin in protection. Just under these membrane bones are the gill covers, of true bone. Which

consists of more parts, the membranous layer, or the true bony layer in the gill cover? (Figs. 211 and 212.)

Is the **mouth** large or small? Are the *teeth* blunt or pointed? Near the outer edge, or far in the mouth? (Fig. 212.) Does the fish have lips? Are the teeth in one continuous row in either jaw? In the upper jaw there are also teeth on the premaxillary bones. These bones are in front of the maxillary bones, which are without teeth. Teeth are also found in the roof of the mouth, and the tongue bears horny appendages similar to teeth. Are the teeth of the fish better suited for chewing or for

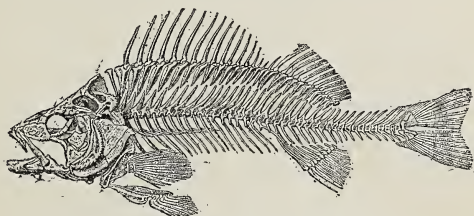


FIG. 212. — SKELETON OF PERCH.

grasping? Why are teeth on the tongue useful? Watch a fish eating: does it chew its food? Can a fish taste? Test by placing bits of brown paper and food in a vessel or jar containing a live fish. Is the throat, or gullet, of the fish large or small?

The **skeleton** of a fish is simpler than the skeleton of other backboned animals. Study Fig. 212 or a prepared skeleton. At first glance, the skeleton appears to have two vertebral columns. Why? What bones does the fish have that correspond to bones in the human skeleton? Are the projections (processes) from the vertebræ long or short? The *ribs* are attached to the vertebræ of the trunk, the last rib being above the vent. The tail begins at the

vent. Are there more tail vertebræ or trunk vertebræ? Are there any neck (cervical) vertebræ (*i.e.* in front of those that bear ribs)? The first few ribs (how many?) are attached to the central body of the vertebræ. The re-

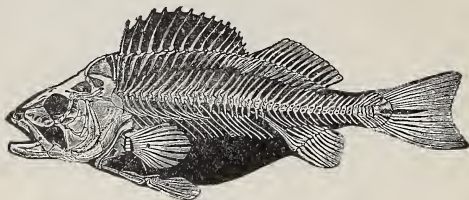


FIG. 213.

maining ribs are loosely attached to processes on the vertebræ. The ribs of bony fishes are not homologous with the ribs of the higher vertebrates. In most fishes there are bones called intermuscular bones attached to the first ribs (how many in the perch?) which are possibly homologous to true ribs; that is, true ribs in the higher vertebrates may have been developed from such beginnings.

Which, if any, of the *fin skeletons* (Fig. 214) are not attached to the general skeleton? Which fin is composed chiefly of tapering, pointed rays? Which fins consist of



FIG. 214. — SOFT-RAYED AND SPINY-RAYED FINS.

rays which subdivide and widen toward the end? Which kind are stiff, and which are flexible? Which of

the fin rays are segmented, or in two portions? The outer segment is called the radial, the inner the basal segment. Which segments are longer? There is one basal segment that lacks a radial segment. Find it (Fig. 212).

What is the advantage of the backbone plan of structure over the armour-plate plan? You have seen the spool-like body of the vertebra in canned salmon. Is it concave, flat, or convex at the ends?

The gills are at the sides of the head (Fig. 215) under the opercula, or gill covers. What is the colour of the gills? Do the blood vessels appear to be very near the surface of the gills, or away from the surface? What advantage in this? Are the gills smooth or wrinkled? (Fig. 215.) What advantage? The bony supports of the gills, called the gill arches, are shown in Fig 216. How many arches on each side? The gill arches have projections on their front sides, called gill rakers, to prevent food



FIG. 215. — CARP, with right gill cover removed to show gills.

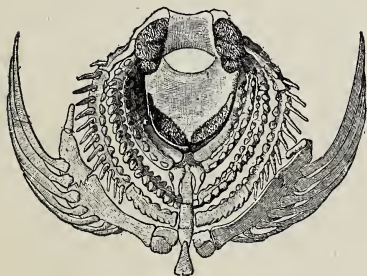


FIG. 216. — SKELETON AROUND THROAT OF FISH.

from being washed through the clefts between the arches. The fringes on the rear of the gill arches are called the gill filaments (Fig. 216). These filaments support the thin and much-wrinkled borders of the gills, for the gills are constructed

on the plan of exposing the greatest possible surface to the water. Compare the plan of the gills and that of the human lungs. The gill opening on each side is guarded by seven rays (Fig. 216) along the hinder border of the

gill cover. These rays grow from the tongue bone. (Fig. 216. This is a rear view.)

Watch a live fish and determine how the water is forced between the gills. Is the mouth opened and closed in the act of breathing? Are the openings behind the gill covers opened and closed? How



FIG. 217. —  
CIRCULATION  
IN GILLS.

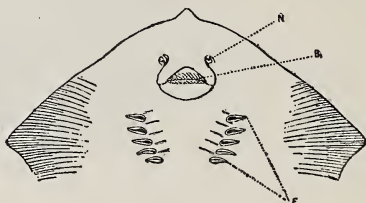


FIG. 218. — NOSTRILS, MOUTH, AND GILL OPENINGS OF  
STING-RAY.

many times per minute does fresh water reach the gills? Do the mouth and the gill covers open at the same time? Why must the water in contact with the gills be changed constantly? Why does a fish usually rest with its head up stream? How may a fish be kept alive for a time after it is removed from the water? Why does drying of the gills prevent breathing? If the mouth of a fish were propped open, and the fish returned to the water, would it suffocate? Why, or why not?



FIG. 219. — GILL OPENINGS OF  
EEL.

**Food Tube.** — The gullet is short and wide. The stomach is elongated (Fig. 220). There is a slight constriction, or narrowing, where it joins the intestine. Is the intestine straight, or does it lie in few or in many loops? (Fig. 220.) The liver has a gall bladder and empties into the intestine through a bile duct. Is the



liver large or small? Simple or lobed? The spleen (*mi*, Fig. 220) lies in a loop of the intestine. The last part of the intestine is straight and is called the rectum. Is it of the same size as the other portions of the intestine? The fish does not possess a pancreas, the most important digestive gland of higher vertebrates.

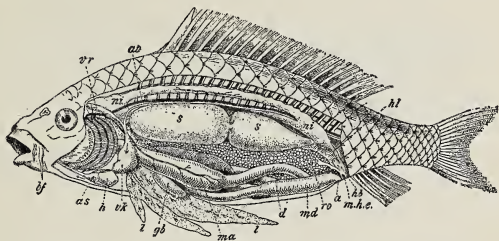


FIG. 220.—ANATOMY OF CARP. (See also coloured figure 4.)

*bf*, barbels on head (for feeling); *h*, ventricle of heart; *as*, aortic bulb for regulating flow to gills; *vk*, venous sinus; *ao*, dorsal aorta; *ma*, stomach; *l*, liver; *gb*, gall cyst; *mi*, spleen; *d*, small intestine; *md*, large intestine; *a*, vent; *s, s*, swim bladder; *ni, ni*, kidney; *hl*, ureter; *hb*, bladder; *ro*, eggs (roe); *mhe*, opening of ducts from kidney and ovary.

Questions: Are the kidneys dorsal or ventral? The swim bladder? Why? Why is the swim bladder double? Does blood enter gills above or below?

The *ovary* lies between the intestine and the air bladder. In Fig. 220 it is shown enlarged and filled with egg masses called roe. It opens by a pore behind the vent. The silver lining of the body cavity is called the peritoneum.

Is the *air bladder* in the perch simple or partly divided? In the carp? (Fig. 220.) Is it above or below the centre of the body? Why? The air bladder makes the body of the fish about as light as water that it may rise and sink with little effort. When a fish dies, the gases of decomposition distend the bladder and the abdomen, and the fish turns over. Why?

Where are the *kidneys*? (Fig. 220.) Their ends unite close under the spinal column. The ureters, or tubes, leading from them, unite, and after passing a small urinary bladder, lead to a tiny urinary pore just behind the opening from the ovary. (Coloured figure 4.)

**The Circulation.**—The fish, unlike other vertebrates, has its breathing organs and its heart in its head. The gills have already been described. The heart of an air-breathing vertebrate is near

its lungs. Why? The *heart* of a fish is near its gills for the same reason. The heart has one auricle and one ventricle. (Coloured figure 1.)

Blood returning to the heart comes through several veins into a *sinus*, or antechamber, whence it passes down through a valve

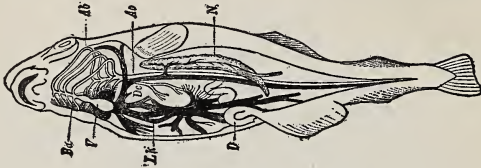


FIG. 221. — PLAN OF CIRCULATION.

*Ab*, arteries to gills; *Ba*, aortic bulb; *V*, ventricle.

into the *auricle*; from the auricle it goes forward into the *ventricle*. The ventricle sends it into an *artery*, not directly, but through a *bulb* (*as*, Fig. 220), which serves to maintain a steady flow, without pulse beats, into the large artery (*aorta*) leading to the gills. The arteries leading from the gills join to form a *dorsal aorta* (*Ao*, Fig. 221), which passes backward, inclosed by the lower processes of the spinal column. After going through the *capillaries* of the various organs, the blood returns to the heart through veins.



FIG. 222. — BRAIN OF PERCH, from above.

*n*, end of nerve of smell;  
*au*, eye; *v*, *z*, *m*, fore,  
mid, and hind brain;  
*h*, spinal bulb; *r*, spinal  
cord.

The *colour of the blood* is given by red corpuscles. These are nucleated, oval, and larger than the blood corpuscles of other vertebrates. The blood of the fish is slightly above the temperature of the water it inhabits.

Notice the general shape of the **brain** (Fig. 222). Are its subdivisions distinct or indistinct? Are the lobes in pairs? The middle portion of the brain is the widest, and consists of the two *optic lobes*. From these lobes the optic nerves pass beneath the brain to the eyes (*Sn*, Fig. 223). In

front of the optic lobes lie the two cerebral lobes, or the *cerebrum*. The small *olfactory lobes* are seen (Fig. 224) in front of the cerebrum. The olfactory nerves may be traced to the nostrils. Behind the optic lobes (mid brain) is the cerebellum (hind brain) and behind it is the *medulla oblongata* or beginning of the spinal cord.



FIG. 223.—BRAIN OF PERCH,  
side view.



FIG. 224.—BRAIN OF PERCH,  
from above.

If you take the eyeball for comparison, is the whole brain as large as one eyeball? (Fig. 222.) If you judge from the size of the parts of the brain, which is more important with the fish, thinking or perception? Which is the most important sense?

The scales along a certain line on each side of the fish, called the lateral line, are perforated over a series of lateral line sense organs, supposed to be the chief organs of *touch* (see Fig. 209).

**Questions.** — Which of the fins of the fish have a use which corresponds to the keel of a boat? The rudder? A

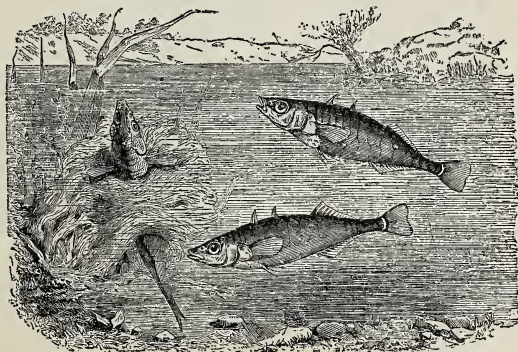


FIG. 225.—THE STICKLEBACK. Instead of depositing the eggs on the bottom, it makes a nest of water plants — the only fish that does so — and bravely defends it,

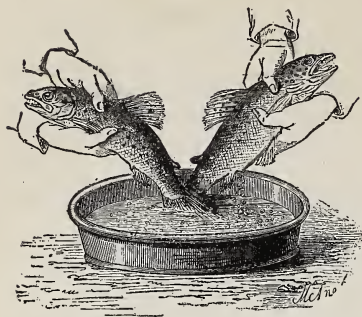


FIG. 226. — ARTIFICIAL FECUNDATION. The egg-cells and sperm-cells are pressed out into a pan of water.

bourhood; in the markets of your town.

**Reproduction.**— The female fish deposits the unfertilized eggs, or ova, in a secluded spot on the bottom. Afterward the male fish deposits the sperms in the same place (see Fig. 225). The eggs, thus unprotected, and newly hatched fish as well, are used for food by fish of the same and other species. To compensate for this great destruction, most fish lay (spawn) many thousands of eggs, very few of which reach maturity. Higher vertebrates (*e.g.* birds) have, by their superior intelligence, risen above this wasteful method of reproduction. Some kinds of marine fish, notably cod, herring, and salmon, go many miles up fresh rivers

to spawn. It is possible that this is because they were originally fresh-water species; yet they die if placed in fresh water except during the spawning season. They go

paddle for sculling? An oar? State several reasons why the head of the fish must be very large, although the brain is very small. Does all the blood go to the gills just after leaving the heart?

Make a list of the different species of fish found in the waters of your neigh-



FIG. 227. — NEWLY HATCHED TROUT, with yolk-sac adhering, eyes large, and fins mere folds of the skin. (Enlarged.)

because of *instinct*, which is simply an inherited habit. Rivers may be safer than the ocean for their young. They are worn and exhausted by the journey, and never survive to lay eggs the second time.

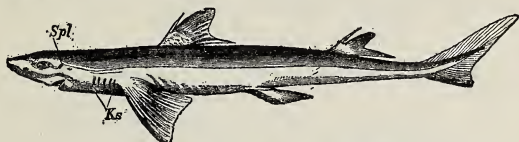


FIG. 228. — A SHARK (*Acanthias vulgaris*).

The *air bladder* is developed from the food tube in the embryo fish, and is homologous with lungs in the higher vertebrates. Are their functions the same?

Fish that *feed on flesh* have a short intestine. Those that eat plants have a long intestine. Which kind of food is more quickly digested?

There are *mucous glands in the skin* of a fish which supply a secretion to facilitate movement through the water; hence a freshly caught fish, before the secretion has dried, feels very slippery.

The air bladder, although homologous to lungs, is not a breathing organ in common fishes. It is filled by the formation of gases from the blood, and can be made smaller by the contraction of muscles along the sides of the body; this causes the fish to sink. In the gar and other ganoids, the air bladder contains blood vessels, is connected with the gullet, and is used in breathing. Organs *serving the same purpose* in different animals are said to be *analogous*. To what in man are the gills of the fish analogous? Organs having *a like position and origin* are said to be *homologous*. The air bladders of a fish are homologous with the lungs of man; but since they have not the same use they are not analogous.



How does the tail of a shark or a gar differ from the tail of common fishes? (Fig. 228.) Do you know of fish destitute of scales? Do you know of fish with whiplike feelers on the head? (Figs.) Why are most fishes white on the under side?

**Comparative Review.** — (Copy table on one page or two facing pages of notebook.)

	IS THERE A HEAD? A NECK?	METHOD OF FEEDING	DIGESTIVE ORGANS AND DIGESTION	REPRODUC- TION	SENSES
Amœba					
Sponge					
Hydra					
Starfish					
Earthworm					
Wasp					
Mussel					
Fish					



FIG. 229. — DRAWING THE SEINE,





FIG. 230.—SUNFISH.

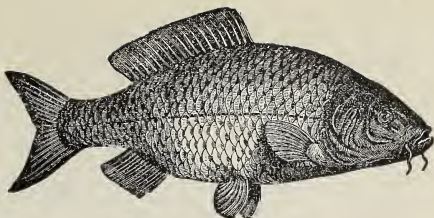


FIG. 235.—CARP.



FIG. 231.—TUNNY.



FIG. 236.—HERRING.



FIG. 232.—SWORDFISH.

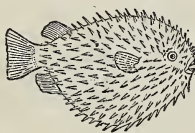


FIG. 233.—SWELLFISH.



FIG. 237.—SPECKLED TROUT.

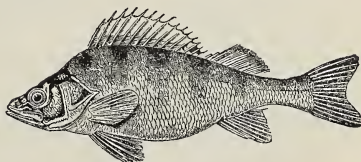


FIG. 238.—PERCH.

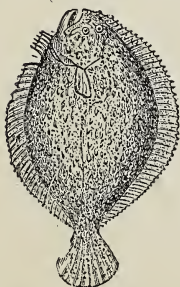


FIG. 234.—TURBOT.



FIG. 239.—SALMON.

Seven Food Fish. Three Curious Fish.  
SPECIAL REPORTS. (Encyclopedia, texts, dictionary.)



FIG. 240.—  
SEA-HORSE.  
(*Hippocampus*),  
with incubat-  
ing pouch, Brt.



FIG. 243.— LANTERN FISH (*Linophryne lucifer*). (After Collett.)



FIG. 244.— LUNG FISH of Australia  
(*Ceratodus miolepis*).

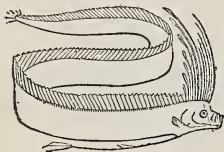


FIG. 241.— BAND FISH.

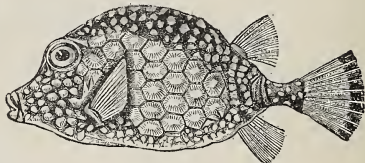


FIG. 245.— TRUNK FISH.

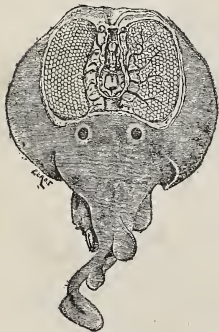


FIG. 242.— TORPEDO. Elec-  
trical organs at right and  
left of brain.

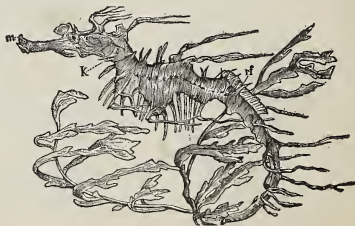


FIG. 246.— SEAWEED FISH.  $\times \frac{1}{2}$   
(*Phyllopteryx eques*).

Remarkable Fish. SPECIAL REPORTS. (Encyclopedia, texts, dictionary.)

## RECOGNITION GROUP CHARACTERS

The commoner members of the several branches may be recognized by the following characters:—

1. The **Protozoans** are the only one-celled animals.
2. The **Sponges** are the only animals having pores all over the body for the inflow of water.
3. The **Polyps** are the only many-celled animals having a single opening into the body, serving for both mouth and vent. They are radiate in structure, and usually possess tentacles.
4. The **Echinoderms** are marine animals of more or less radiate appearance, having a food tube in the body separate from the body wall.

The following groups are plainly bilateral: that is, dorsal and ventral surfaces, front and hind ends are different.

5. The **Vermes** have usually a segmented body but lack jointed legs.
6. The **Arthropods**<sup>1</sup> have an external skeleton and jointed legs.
7. The **Molluscs** have soft bodies, no legs, no skeleton, but usually a limy shell.
8. The **Vertebrates** have an internal skeleton of bones, and usually two pairs of legs.

<sup>1</sup> Insects and crustaceans.



FIG. 247.—A SNAIL. (Which branch? Why?)

## CHAPTER XI

### BATRACHIA

The theory of evolution teaches that animal life began in a very simple form in the sea, and that afterward the higher sea animals lost their gills and developed lungs and legs and came out to live upon the land; truly a marvellous procedure, and incredible to many, although the process is repeated every spring in countless instances in pond and brook.

In popular language, every cold-blooded vertebrate breathing with lungs is called a reptile. The name reptile is properly applied only to lizards, snakes, turtles, and alligators. The common mistake of speaking of frogs and salamanders as reptiles arises from considering them only in their adult condition. Reptiles hatch from the egg as tiny reptiles resembling the adult forms; frogs and salamanders, as every one knows, leave the egg in the form of tadpoles (Fig. 248). The fact that frogs and salamanders begin active life as fishes, breathing by gills, serves to distinguish them from other cold-blooded animals; and causes naturalists to place them in a separate class, called batrachia (twice breather) or amphibia (double life).

### TADPOLES

SUGGESTIONS. — Tadpoles may be studied by placing a number of frog's eggs in a jar of water, care being taken not to place a large number of eggs in a small amount of water. When they hatch, water plants (*e.g.* green algæ) should be added for food. The behaviour of frogs may be best studied in a tub of water. A toad in captivity should be given a cool, moist place, and fed well. A piece of meat placed near a toad may attract flies, and the toad may be observed while catching them, but the motion is so swift as to be almost imperceptible. Live flies may be put into a glass jar with a toad. Toads do not move about until twilight, except

in cloudy, wet weather. They return to ponds and brooks in spring at the time for laying eggs. This time for both frogs and toads is shown by trilling. All frogs, except tree frogs, remain in or near the water all the year.

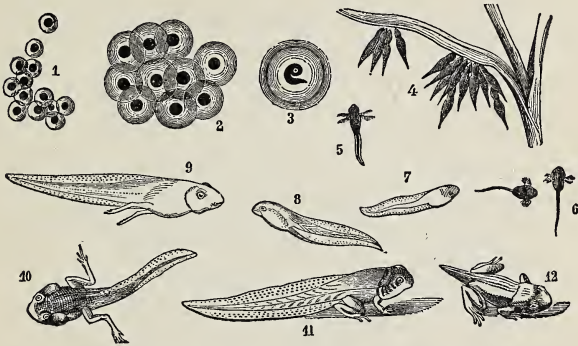


FIG. 248.—METAMORPHOSES OF THE FROG, numbered in order.

Do eggs hatch and tadpoles grow more rapidly in a jar of water kept in a warm place or in a cold place? In pond water or in drinking water? Can the tadpoles be seen to move in the eggs before hatching? When do the external gills show? (Fig. 248.)

What parts may be described in a tadpole? What is the shape of the tail? *Compare the tadpole with the fish* as to (1) general shape, (2) covering, (3) fins, (4) tail, (5) gills.



FIG. 249.—TADPOLE, from below, showing intestine and internal gills. (Enlarged.)

Do the external gills disappear before or after any rudiments of limbs appear? (6, 7, Fig. 248.) Can you locate the gills after they become internal? (Fig. 249.)



In what state of growth are the *legs* when the tadpole first goes to the surface to breathe? Which legs appear first? Of what advantage is this? What becomes of the tail? Is the tail entirely gone before the frog first leaves the water? Are tadpoles habitually in motion or at rest?

Is the *intestine* visible through the skin? (Fig. 249.) Is it straight or coiled? Remembering why some fish have larger intestines than others, and that a cow has a long intestine and a cat a short one, state why a tadpole has a relatively longer intestine than a frog.

Compare the mouth, jaws, eyes, skin, body, and habits of *tadpole and frog*.

## FROGS

Prove that frogs and toads are *beneficial to man*. Did you ever know of a frog or a toad destroying anything useful, or harming any one, or causing warts? How many pupils in class ever had warts? Had they handled frogs before the warts came? Frogs are interesting, gentle, timid animals. Why are they repulsive to some people?

**Environment.**—Where are frogs found in greatest numbers? What occurs when danger threatens them? What *enemies* do they have? What colour, or tint, is most prominent on a frog? Does the colour “mimic” or *imitate* its surroundings? What is the colour of the under side of the body? (Fig. 250.) Why is there greater safety in that colour? What enemies would see water frogs from below? Do tree frogs mimic the bark? The leaves?

Can a *frog stay under water* for an indefinite time? Why, or why not? What part of a frog is above the



surface when it floats or swims in a tub of water? Why? Do frogs croak in the water or on the bank? Why do they croak after a rain? Do toads croak?

Are the *eggs* laid in still or in flowing water? In a clear place or among sticks and stems? Singly, or in strings or in masses? (Fig. 248.) Describe an egg. Why do frogs dig into the mud in autumn in cold climates? Why do they not dig in mud at the bottom of a pond?



FIG. 250. — PAINTED FROG (*Chorophilus ornatus*), of Mexico.

Describe the **position** of the frog when still (Fig. 250). Of what advantage in this position? Does the frog use its fore legs in swimming or jumping? Its hind legs? How is the frog fitted for jumping? Compare it in this respect with a jumping insect; a jumping mammal. How is it fitted for swimming? Is the general build of its body better fitted for swimming or for jumping? How far can a frog jump?

**External Features.** — The frog may be said to have two *regions in its body*, the head and the trunk. A neck hardly

exists, as there is only one vertebra in front of the shoulders (Fig. 252), while mammals have seven neck (cervical) vertebræ. There are no tail (caudal) vertebræ, even in the tadpole state of frogs and toads.

The *head* appears triangular in shape when viewed from what direction? The head of a frog is more pointed than the head of a toad. Is the skull a closed case of broad bones or an open structure of narrow bones? (Fig. 252.)

Describe the *mouth*. Observe the extent of the mouth opening (Fig. 251). Are *teeth* present in the upper jaw? The lower jaw? Are the teeth sharp or dull? Does the



FIG. 251.—HEAD OF FROG.

frog chew its food? Is the *tongue* slender or thick? (Fig. 251.) Is it attached to the front or the back of the mouth? In what direction does the free end extend when the tongue lies flat? Is the end pointed or lobed? How far out will the tongue stretch? For what is it

used? Why is it better for the teeth to be in the upper jaw rather than in the lower jaw? That the teeth are of little service is shown by the fact that the toad with similar habits of eating has no teeth. Will a toad catch and swallow a bullet or a pebble rolled before it? The toad is accustomed to living food, hence it prefers a moving insect to a still one.

**The Senses.**—Compare the *eyes* with the eyes of a fish in respect to position and parts. Are the eyes protruding or deep-set? Touch the eye of a live frog. Can it be retracted? What is the shape of the pupil? The colour of the iris? Is the eye bright or dull? What probably gave rise to the superstition that a toad had a jewel in its head? Is there a third eyelid? Are the

upper and lower eyelids of the same thickness? With which lid does it wink? Close its eye?

Observe the large oval *ear* drum or tympanum. What is its direction from the eye? (Fig. 251.) The mouth? Is there a projecting ear? Does the frog hear well? What reason for your answer? As in the human ear, a tube (the Eustachian tube) leads from the mouth to the inner side of the tympanum.

How many *nostrils*? (Fig. 251.) Are they near together or separated? Large or small? A bristle passed into the nostril comes into the mouth not far back in the roof. Why must it differ from a fish in this?

How do the *fore and hind legs* differ? How many toes on the fore foot or hand? On the hind foot? On which foot is one of the toes rudimentary? Why is the fore limb of no assistance in propelling the body in jumping? Do the toes turn in or out? (Fig. 250.) How does the frog give direction to the jump? What would be the disadvantage of always jumping straight forward when fleeing? Which legs are more useful in alighting?

**Divisions of the Limbs.**—Distinguish the upper arm, forearm, and hand in the

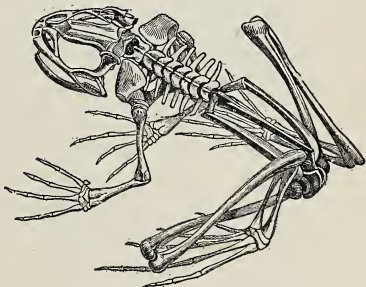


FIG. 252.—SKELETON OF FROG.

fore limb (Figs. 252 and 253). *Compare with skeleton of man* (Fig. 399). Do the arms of a man and a frog both have one bone in the *upper arm* and two in the *forearm*? Both have several closely joined bones in the *wrist* and

five separate bones in the *palm*. Do any of the frog's fingers have three joints? *Compare also the leg of man*

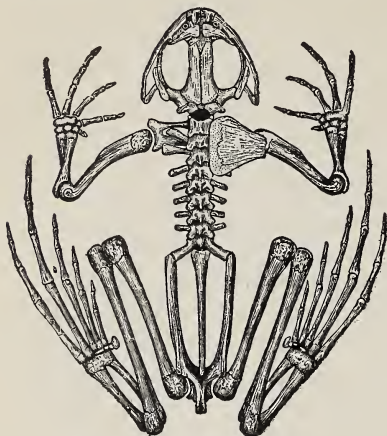


FIG. 253.—SKELETON OF FROG.

and the hind leg of the frog (Figs. 253 and 399). Does the *thigh* have one bone in each? The shank of man has two bones, shin and splint bone. Do you see a groove near the end in the shank bone of a frog (Fig. 252), indicating that it was formed by the union of a shin and a splint bone? The

first two of the five bones of the ankle are elongated, giving the hind leg the appearance of having an extra joint (Fig. 253). The foot consists of six digits, one of which, like the thumb on the fore limb, is rudimentary. The five developed toes give the five digits of the typical vertebrate foot. Besides the five bones corresponding to the instep, the toes have two, three, or four bones each. How is the hind foot specialized for swimming? Which joint of the leg contains most muscle? (Fig. 254.) Find other bones of the frog analogous in position and similar in form to bones in the human skeleton.



FIG. 254.—LEG MUSCLES OF FROG.

Is the **skin** of a frog tight or loose? Does it have any appendages corresponding to scales, feathers, or hair of other vertebrates? Is the skin rough or smooth? The toad is furnished with glands in the skin which are sometimes swollen; they form a bitter secretion, and may be, to some extent, a protection. Yet birds and snakes do not hesitate to swallow toads whole. Show how both upper and under surfaces of frog illustrate protective coloration.

All batrachians have large and *numerous blood vessels in the skin* by which gases are exchanged with the air, the skin being almost equal to *a third lung*. That the skin may function in this way, it must not become dry. Using this fact, account for certain habits of toads as well as frogs.

If a frog is kept in the dark or on a dark surface, *its skin will become darker* than if kept in the light or on a white dish. Try this experiment, comparing two frogs. This power of changing colour is believed to be due to the diminution in size of certain pigment cells by contraction, and enlargement from relaxation. This power is possessed to a certain degree not only by batrachians but also by many fishes and reptiles. The chameleon, or green lizard, surpasses all other animals in this respect (Fig. 280). What advantage from this power?

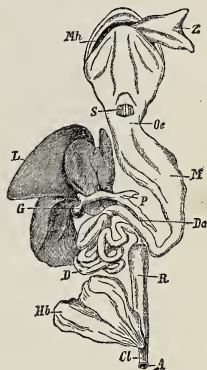


FIG. 255. — DIGESTIVE CANAL OF FROG.

*Mh*, mouth; *Z*, tongue pulled outward; *S*, opening to larynx; *Oe*, gullet; *M*, stomach; *D*, intestine; *P*, pancreas; *L*, liver; *G*, gall bladder; *R*, rectum; *Hb*, bladder; *Cl*, cloaca; *A*, vent.

**Digestive System.** — The large mouth cavity is connected by a short throat with the gullet, or œsophagus (Fig. 255).

A slit called the glottis opens from the throat into the lungs (Fig. 255). Is the gullet long or short? Broad or narrow? Is the stomach short or elongated? Is the division distinct between stomach and gullet, and stomach and intestine? Is the liver large or small? Is it simple or lobed? The pancreas lies between the stomach and the first bend of the intestines (Fig. 255). What is its shape? A bile duct connects the liver with

the small intestine (*Dc*, Fig. 255). It passes through the pancreas, from which it receives several pancreatic ducts. After many turns, the small intestine joins the large intestine. The last part of the large intestine is called the rectum (Latin, straight). The last part of the rectum is called the cloaca (Latin, a drain), and into it the ducts from the kidneys and the reproductive glands also open. The kidneys are large, elongated, and flat. They lie under the dorsal wall. The urinary bladder is also large. Does the salamander have a similar digestive system? (Fig. 256)



FIG. 256. — ANATOMY OF SALAMANDER.

1 *a*, heart; 2, lungs; 3 *a*, stomach; 3 *b*, intestine; 3 *c*, large intestine; 4, liver; 8, egg masses; 10, bladder; 11, vent.

under the dorsal wall. The urinary bladder is also large. Does the salamander have a similar digestive system? (Fig. 256) Why are the liver and the lungs (Fig. 256) longer in a salamander than in a frog?

**Respiration.** — How many *lungs*? Are they simple or lobed? (Fig. 256.) A lung cut open is seen to be baglike, with numerous ridges on its inner surface. This increases the surface with which the air may come in contact. In the walls of the lungs are numerous



capillaries. Does the frog *breathe with mouth open or closed?* Does the frog have any ribs for expanding the chest? What part of the head expands and contracts? Is this motion repeated at a slow or a rapid rate? Regularly or irregularly? There are valves in the nostrils for opening and closing them. Is there any indication of opening and closing as the throat expands and contracts? The mouth and throat (pharynx) are filled with air each time the throat swells, and the exchange of gases (which gases?) takes place continually through their walls and the walls of the lungs. At intervals the air is forced through the glottis into the lungs. After a short time it is expelled from the lungs by the muscular abdominal walls, which press upon the abdominal organs, and so upon the lungs. Immediately the air is forced back into the lungs, so that they are kept filled. In some species the lungs regularly expand at every second contraction of the throat. This is shown by a slight outward motion at the sides. Does the motion of the throat cease when the frog is under water? Why would the frog be unable to breathe (except through the skin) if its mouth were propped open? Why does the fact that the breathing is so slow as almost to cease during hibernation, aid the frog in going through the winter without starving? (Chap. I.) Why must frogs and toads keep their skins moist? Which looks more like a clod? Why?

**The Heart and Circulation.** — What is the shape of the heart? (Fig. 257.) Observe the two auricles in front and the conical ventricle behind them. The great arterial trunk from the ventricle passes forward beyond the auricles; it divides into two branches which turn to the right and the left (Fig. 257). Each branch immediately subdivides into three arteries (Fig. 257), one going to the head, one to the lungs and skin, and a third, the largest,

passes backward in the trunk, where it is united again to its fellow.

Both the pulmonary veins, returning to the heart with pure blood from the lungs, empty into the left auricle. Veins with the impure blood from the body empty into the right auricle. Both the auricles empty into the ventricle, but the pure and the impure blood are prevented from thoroughly mixing by ridges on the inside of the ventricle. Only in an animal with a four-chambered heart does pure blood from the lungs pass unmixed and pure to all parts of the body,

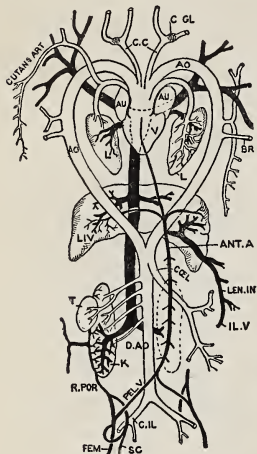


FIG. 257.—PLAN OF FROG'S CIRCULATION.

Venous system is black; the arterial, white. *AU*, auricles; *V*, ventricle; *L*, lung; *LIV*, liver. Aorta has one branch to right, another to left, which reunite below. Right branch only persists in birds, left branch in beasts and man.

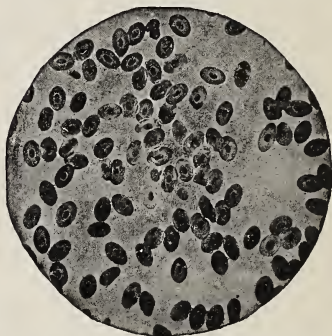


FIG. 258.—FROG'S BLOOD (magnified 2500 areas). Red cells oval, nucleated, and larger than human blood cells. Nuclei of two white cells visible near centre. (Peabody.)

and only such animals are warm-blooded. The purer (*i.e.* the more oxygenated) the blood, the greater the oxidation and warmth.

The red corpuscles in a frog's blood are oval and larger than those of man. Are all of them nucleated? (Fig. 258.) The flow of blood in the web of a frog's foot is a striking and interesting sight. It may be easily shown by wrapping a small frog in a wet cloth and laying it with one foot extended upon a glass slip on the stage of a microscope.

The **brain** of the frog (Fig. 259) is much like that of a fish (Fig. 224). The *olfactory*, *cerebral*, and *optic lobes*, *cerebellum*, and *medulla* are in the same relative position, although their relative sizes are not the same. Compared with the other parts, are the olfactory lobes more or less developed than in a fish? The cerebral hemispheres? The optic lobes? The cerebellum? There is a cavity in the brain. It is readily exposed on the under surface of the medulla by cutting the membrane, which is there its only covering (Fig. 259).

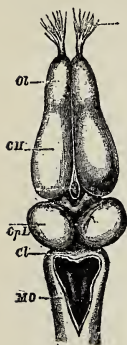


FIG. 259. —  
BRAIN OF FROG.



FIG. 260. — NERVOUS SYSTEM  
OF FROG.

Frogs and toads are **beneficial** (why?) and do not the slightest injury to any interest of man. If toads are encouraged to take up their abode in a garden, they will aid in ridding it of insects. A house may be made in a shady corner with four bricks, or better still, a hole a foot deep may be dug to furnish them protection from the heat of the day. A toad's muzzle is not so tapering as a frog's (why?), its feet are not so fully webbed (why?), and its skin is not so smooth (why?). In case of doubt, open the mouth and rub the finger along the upper jaw; a frog has sharp teeth, a toad none at all. The tadpoles of frogs, toads, and salamanders are much alike. In toad's spawn the eggs lie in strings inclosed in jelly; frogs spawn is in masses (Fig. 248).

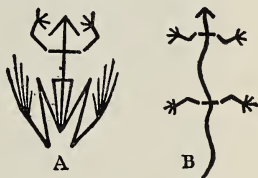


FIG. 261. — Position of legs in tailless (A) and tailed (B) amphibian.

Any batrachian may easily be passed around the class after placing it in a tumbler with gauze or net tied over top. It should be kept in a box with two inches of moist earth on the bottom. If no live insects are obtainable for feeding a toad, bits of moist meat may be dangled from the end of a string. If tadpoles are placed in a pool or a tub in a garden, the toads hatched will soon make destructive garden insects become a rarity.

Does a frog or a **salamander** have the more primitive form of body? Why do you think so? Salamanders are sometimes called mud puppies. The absurd belief that salamanders are poisonous is to be classed with the belief that toads cause warts. The belief among the ancients that salamanders ate fire arose perhaps from seeing them coming away from fires that had been built over their holes on river banks by travellers. Their moist skin protected them until the fire became very hot.

Describe the "mud puppy" shown in Fig. 262. The pouched gopher, or rat (Fig. 371), is sometimes absurdly called a salamander.

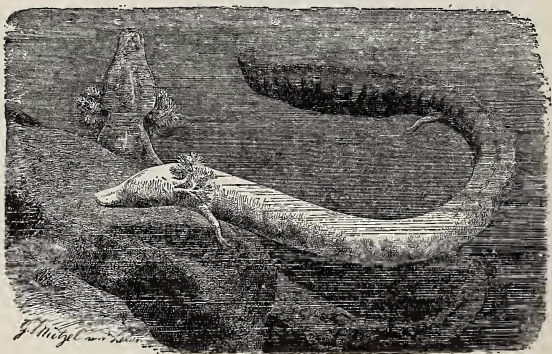


FIG. 262. — BLIND SALAMANDER (*Proteus anguinus*).  $\times \frac{1}{2}$ . Found in caves and underground streams in Balkans. Gills external, tail finlike, legs small.

## CHAPTER XII

### REPTILIA (REPTILES)

This class is divided into *four orders* which have such marked differences of external form that there is no difficulty in distinguishing them. These orders are represented by *Lizards*, *Snakes*, *Turtles*, and *Alligators*. Of these, only the forms of lizards and alligators have similar proportions, but there is a marked difference in their size, lizards being, in general, the smallest, and alligators the largest of the reptiles.

**Comparison of Lizards and Salamanders.** — To make clear the difference between reptiles and batrachians, it will be well to compare the orders in the two classes which resemble each other in size and shape; namely, lizards and



FIG. 263. — A SALAMANDER.



FIG. 264. — A LIZARD.

salamanders (Figs. 263 and 264). State in a tabular form their differences in *skin*, *toe*, *manner of breathing*, *development from egg*, *shape of tail*, *habitat*, *habits*. Each has an elongated body, two pairs of limbs, and a long tail, yet they are easily distinguished. Are the differences suggested above valid for the other batrachians (frogs) and other reptiles (*e.g.* turtles)? Trace the same differences



between the toad or frog (Fig. 250) and the "horned toad," which is a lizard (Fig. 265).

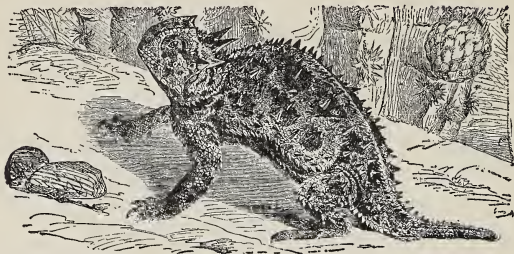


FIG. 265. — "HORNED TOAD" LIZARD, of the Southwest (*Phrynosoma cornuta*).  $\times \frac{2}{3}$ .

### STUDY OF A TURTLE OR A TORTOISE

SUGGESTIONS. — Because of the ease with which a tortoise or a turtle may be caught and their movements and habits studied, it is suggested that one of these be studied as an example of reptiles. Besides a live specimen, a skeleton of one species and the shells of several species should be available.

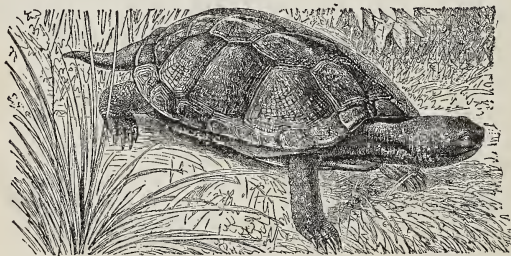


FIG. 266. — EUROPEAN POND TURTLE (*Emys lutaria*). (After Brehms.)

The body (of a turtle or a tortoise) is divided distinctly into *regions* (Fig. 266). Is there a head? Neck? Trunk? Tail? The trunk is inclosed by the so-called *shell*, which



consists of an upper portion, the *carapace*, and a lower portion, the *plastron*. How are the other regions covered? What is the shape of the head? Is the mouth at the front, or on the under side? Where are the *nostrils*? Are the motions of breathing visible? Is there a beak or snout? Do the jaws contain *teeth*?

Do the **eyes** project? Which is thinner and more movable, the upper or the lower lid? Identify the third eyelid (*nictitating membrane*). It is translucent and comes from, and is drawn into, the inner corner of the eye. It cleanses the eyeball. Frogs and birds have a similar membrane. The circular **ear** drum is in a depression back of the angle of the mouth. What other animal studied has an external ear drum?

The tortoise has a longer, more flexible **neck** than any other reptile. Why does it have the greatest need for such a neck? Is the skin over the neck tight or loose? Why?

Do the **legs** have the three joints or parts found on the limbs of most vertebrates? How is the skin of the legs covered? Do the toes have *claws*? Compare the front and the hind feet. Does the tortoise slide its body or lift it when walking on hard ground? Lay the animal on its back on a chair or a table at one side of the room in view of the class. Watch its attempts to right itself. Are the motions suited to accomplish the object? Does the tortoise succeed?

What are the prevailing **colours** of turtles? How does their coloration correspond to their surroundings?

What parts of the tortoise extend at times beyond the shell? Are any of these parts visible when the *shell is closed*? What movements of the shell take place as it is closed? Is the carapace rigid throughout? Is the plastron?

**The Skeleton** (Fig. 267). — The *carapace* is covered with thin *epidermal plates* which belong to the skin. The bony nature of the carapace is seen when the plates are removed, or if its inner surface is viewed (Fig. 267). It is seen to consist largely of wide *ribs* (how many?) much flattened and grown together at their edges. The ribs are seen to be rigidly attached to the vertebræ. The rear projections of the vertebræ are flattened into a series of bony plates which take the place of the sharp ridge found along the backs of most

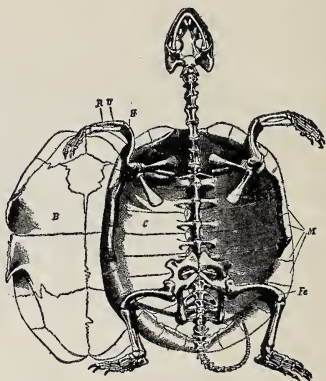


FIG. 267. — SKELETON OF EUROPEAN TORTOISE.

C, rib plates; M, marginal plates; B, plastron; H, humerus bone; R, radius; U, ulna; Fe, femur.

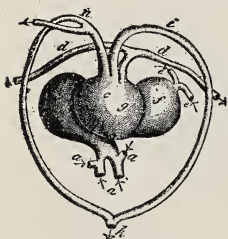


FIG. 268. — THREE-CHAMBERED HEART OF A REPTILE (tortoise).

a, veins; b, f, right and left auricles; c, ventricle; d, arteries to lungs; e, veins from lungs; z, n, two branches of aorta. Compare with Fig. 269 and coloured Fig. 2.

vertebrates. Show that the shell of a turtle is not homologous with the shells of molluscs. Does the turtle have shoulder blades and collar bones? Hip bones? Thigh bones? Shin bone (fibia) and splint bone (fibula)? (Fig. 267.)

Do the plates formed by the ribs extend to the edge of the carapace? See Fig. 267. About how many bony plates form the carapace? The plastron? Do the horny plates outside correspond to the bony plates of the shell?

How many axial plates? How many costal (rib) plates? How many border plates? Which plates are largest? Smallest? Do the horny plates overlap like shingles, or meet edge to edge? Is there any mark where they meet on the bony shell? Basing it upon foregoing facts, give a connected and complete description of the structure of the carapace. Compare the skeleton of the turtle with that of the snake, and correlate the differences in structure with differences in habits.

Draw the tortoise seen from the side or above, with its shell closed, showing the arrangement of the plates.

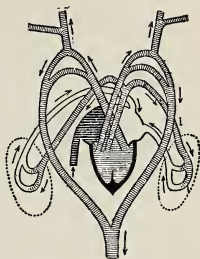


FIG. 269.—PLAN OF REPTILIAN CIRCULATION. See arrows.

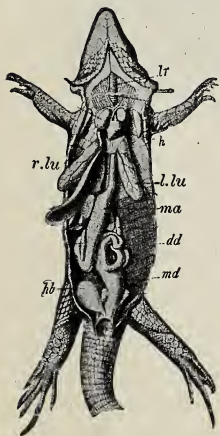


FIG. 270.—REPTILIAN VISCERA (lizard).

*lr*, windpipe; *h*, heart; *lu*, lungs; *lr*, liver; *ma*, stomach; *dd*, intestines; *hb*, bladder.

Place soft or tender vegetable food, lettuce, mushroom, roots, berries, and water, also meat, in reach of the turtle. What does it prefer? How does it eat? It has no lips; how does it drink?

Study the **movements** of its eyeballs and eyelids, and the respiratory and other movements already mentioned. State a reason for thinking that no species of land animals exists that lacks the simple power of righting itself when turned on its back.

**Tortoise, Turtle, Terrapin.** — The turtles belong to the order of reptiles called *chelonians*. No one

can have any difficulty in knowing a member of this order. The subdivision of the order into families is not so easy, however, and the popular attempts to classify chelonians as turtles, tortoises, and terrapins have not been entirely successful. Species with a vaulted shell and imperfectly webbed toes and *strictly terrestrial* habits are called *tortoises*. Species with flattened shells and *strictly aquatic* habits should be called *terrapins* (e.g. mud terrapin). They have three instead of two joints in the middle toe of each foot. The term *turtle* may be applied to species which are *partly terrestrial and partly aquatic* (e.g. snapping turtle (Fig. 271)). Usage, however, is by no means uniform.

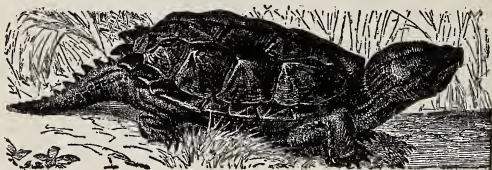


FIG. 271. — SNAPPING TURTLE (*Chelydra serpentina*).

Most reptiles eat animal food ; green terrapins and some land tortoises eat vegetable food. Would you judge that carnivorous chelonians catch very active prey ?

The fierce *snapping turtle*, found in ponds and streams, sometimes has a body three feet long. Its head and tail are very large and cannot be withdrawn into the shell. It is carnivorous and has great strength of jaw. It has been known to snap a large stick in two. The *box tortoise* is yellowish brown with blotches of yellow, and like its close kinsman, the pond turtle of Europe (Fig. 266), withdraws itself and closes its shell completely. Both lids of the plastron are movable, a peculiarity belonging to these two species. The *giant tortoise* of the Galapagos Islands, ac-

according to Lyddeker, can trot cheerfully along with three full-grown men on its back. "Tortoise shell" used for combs and other articles is obtained from the overlapping scales of the *hawkbill turtle*, common in the West Indies. The *diamond-back terrapin*, found along the Atlantic Coast from Massachusetts to Texas, is prized for making soup.

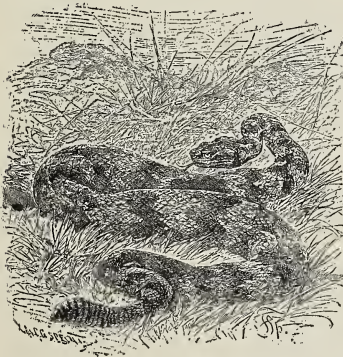


FIG. 272.—A RATTLESNAKE.

**Venomous snakes** named in order of virulence: 1. Coral snakes, *Elaps*, about seventeen red bands bordered with yellow and black (coloured figure 6) (fatal). 2. Rattlesnakes (very deadly). 3. Copperhead (may kill a small animal of the size of a dog). 4. Water moccasin (never fatal). 5. Ground rattler.—*Effects*: Pulse fast, breathing slow, blood tubes dilated, blood becomes stored in abdominal blood tubes, stupefaction



FIG. 273 a.—HEAD OF VIPER, showing typical triangular shape of head of venomous snake.



FIG. 273 b.—SIDE VIEW, showing poison fangs; also tongue (forked, harmless).



FIG. 274.—VIPER'S HEAD, showing poison sac at base of fangs.



FIG. 275.—SKULL, showing teeth, fangs, and quadrate bone to which lower jaw is joined. See Fig. 284.



and death from blood being withdrawn from brain. Always two punctures, the closer together the smaller the snake. *Remedies*: Ligature between wound and heart, lance wound and suck; inject into wound three drops of 1 per cent solution of chromic acid or potassium permanganate. Give strychnine, hypodermically, until strychnine symptoms (twitchings) appear. No one but a physician should give strychnine. Digitalin or caffeine acts like strychnine; alcohol has opposite effect.

**Protective Coloration and Mimicry.**—When an animal imitates the colour or form of its *inanimate surroundings* it is said to be *protectively coloured* or *formed*. Give an instance of *protective coloration* or *form* among lizards; butterflies; grasshoppers; amphibians; echinoderms.



FIG. 276. — "GLASS SNAKE," a lizard without legs.

When an animal imitates the colour or the form of *another animal* it is said to *mimic* the animal. Mimicry usually enables an animal to deceive enemies into mistaking it for an animal which for some reason they avoid. The milkweed butterfly has a taste that is repulsive to birds. The viceroy butterfly is palatable to birds, but it is left untouched because of its close resemblance to the repulsive milkweed butterfly. The harlequin snake (*Elaps*) of the Gulf States is the most deadly snake of North America (Figs. 277, 278). It is very strikingly coloured with rings of scarlet, yellow, and black. This is an example of *warning coloration*. The scarlet snake (*Lampropeltis*) has bands of



FIG. 277. — SKULL OF ELAPS. See coloured Fig. 5.



FIG. 278. = SKULL OF LAMPROPELTIS.



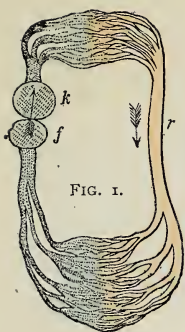


FIG. 1.

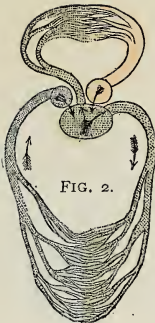


FIG. 2.

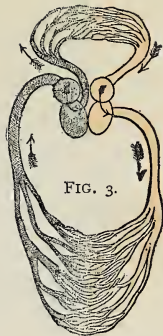


FIG. 3.

COLOURED FIGURES 1, 2, 3.—CIRCULATION IN FISH, REPTILE, MAMMAL.

In which is blood from heart all impure? Mixed? Both pure and impure?

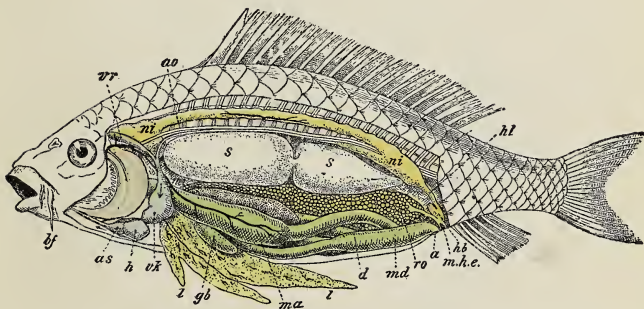


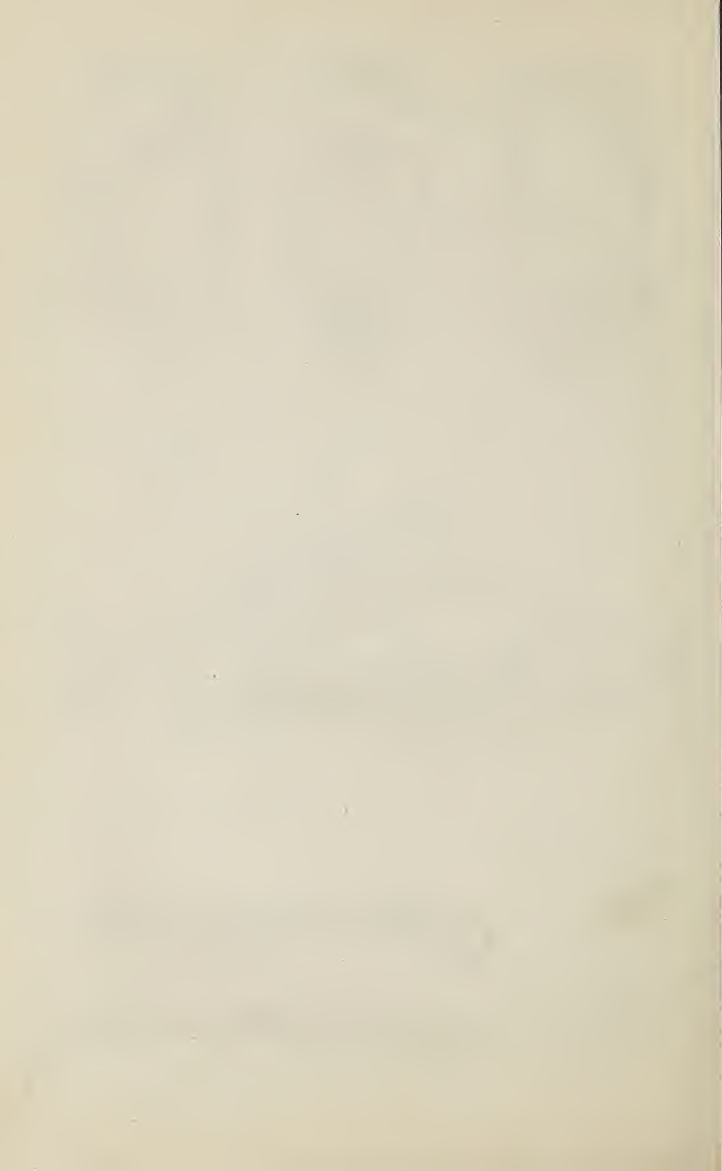
FIG. 4.—ANATOMY OF CARP. For description see Fig. 220, page 117.

FIG. 5.—HARLEQUIN SNAKE (*Elaps*).

THE DEADLY  
HARLEQUIN SNAKE  
IS MIMICKED BY THE  
HARMLESS SCARLET  
SNAKE.



FIG. 6.—SCARLET SNAKE (*Lampropeltis*).



scarlet, yellow, and black (coloured Fig.6) of the same tints, and it is hardly distinguishable from the harlequin. The

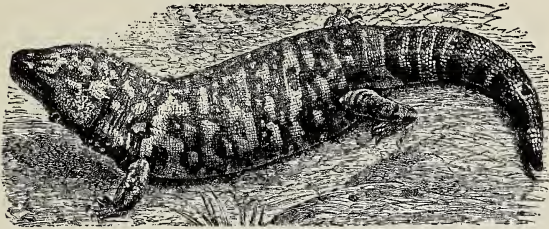


FIG. 279. — GILA MONSTER (*Heloderma suspectum*), of Arizona. If poisonous, it is the only instance among lizards. It is heavy-built, orange and black mottled, and about 16 inches long. Compare it with the green lizard (Fig. 280).

scarlet snake is said to *mimic* the harlequin snake. It also imitates the quiet inoffensive habits of the harlequin snake, which fortunately does not strike except under the greatest provocation. The rattles of the less poisonous but deadly rattlesnake (Fig. 272) may be classed as an example of *warning sound* which most animals are quick to heed and thus avoid encounters which might be destructive to either the snake or its enemy.

**Survival of the Fittest.** — The two facts of most far-reaching importance in the history of animals and plants are: (1) *Heredity*; animals inherit the characteristics of their parents. (2) *Variation*; animals are not exactly like their parents. The first fact gives stability, the second makes



FIG. 280. — CHAMELEON (*Anolis*), or green lizard of southern U.S. Far excels European chameleon (Fig. 281) and all known animals in power of changing colour (green, gray, yellow, bronze, and black).

evolution possible. The climate of the world is slowly changing, and animals must change to adapt themselves to it. A more sudden change of environment (surroundings) of animals occurs because of migration or isolation; these in turn are caused

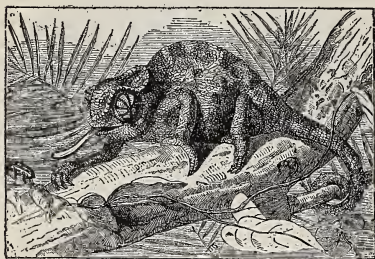


FIG. 281. — CHAMELEON OF SOUTHERN EUROPE.

claws, swifter movements, etc. The individuals possessing such beneficial variations live longer and leave more offspring, and because of heredity transmit the desirable qualities to some of their young. Variations which are disadvantageous for getting food, defence, etc., cause shorter life and fewer offspring. Thus the *fittest survive*, the unfit perish; an automatic *natural selection* occurs.

Darwin taught that variations are infinitesimal and gradual. Recent experiments and observations seem to show that many variations are by sudden jumps, somewhat resembling so-called "freaks of nature." As to whether these "sports," or individuals with new peculiarities, survive, depends upon their fitness for their environment. "Survival of the fittest" results from this natural selection, but the selection occurs between animals of marked, not infinitesimal, differences, as Darwin taught. Darwin's theory is probably true for species in the usual state of nature; the new theory (of De Vries) is probably true for animals and plants under domestication and during rapid geographical changes.

by the crowding of other animals or by the formation or disappearance of geographical barriers, such as deserts, water, mountain chains.

The young vary in many ways from their parents. Some have a more protective

colour or form, sharper



FIG. 282. — EMBRYO OF A TURTLE, showing four gill slits. (Challenger Report.)

Table for Review (for notebooks or blackboards).

	FISH	TADPOLE	FROG	TURTLE	LIZARD
Limbs, kind and number					
Are claws present? How many?					
Covering of body					
Teeth, kind of, if present					
Which bones found in man are lacking?					
Chambers of heart					
Respiration					
Movements					

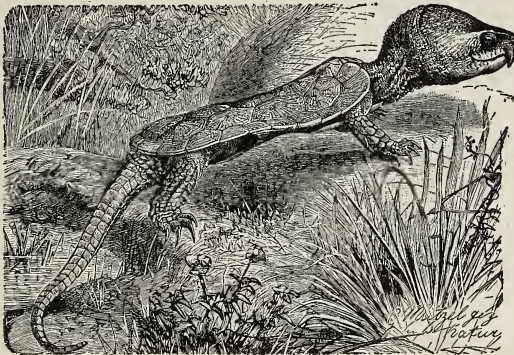


FIG. 283.—BIG-HEADED TURTLE (*Platysternum megaloccephalum*).  $\times \frac{1}{2}$ . China.  
This and Fig. 282 suggest descent of turtles from a lizardlike form. Figure 282 shows earlier ancestors to have been gill breathers.

## CHAPTER XIII

### BIRDS

**SUGGESTIONS.**—The domestic pigeon, the fowl, and the English sparrow are most commonly within the reach of students. The last bird has become a pest and is almost the only bird whose destruction is desirable. The female is somewhat uniformly mottled with gray and brown in fine markings. The male has a black throat with the other markings of black, brown, and white, in stronger contrast than the marking of the female. As the different species of birds are essentially alike in structural features, the directions and questions may be used with any bird at hand. When studying feathers, one or more should be provided for each pupil in the class. The feet and the bills of birds should be kept for study.

Does the body of the bird like the toad and the turtle, have a head, a trunk, a tail, and two pairs of limbs? Do the fore and hind limbs differ from each other more or less than the limbs of other backboned animals? Does any other vertebrate use them for purposes as widely different?

**Eye.**— Does the eyeball have parts corresponding to the eyeball of a fish or a frog; viz., cornea, iris, pupil? Which is more movable, the upper or the lower eyelid? Are there any lashes? The bird (like what other animal?) has a third eyelid, or nictitating membrane. Compare its thickness with that of the other lids. Is it drawn over the eyeball from the inner or the outer corner of the eye? Can you see in the human eye any wrinkle or growth which might be regarded as remains, or vestige, of such a membrane?



How many **nostrils**? In which mandible are they located? Are they nearer the tip or the base of the mandible? (Fig. 284.) What is their shape? Do the nasal passages go directly down through the mandible or do they go backward? Is the inner nasal opening into the mouth or into the throat?

The beak or **bill** consists of the upper and lower mandibles. The outside of the beak seems to be of what kind of material? Examine the decapitated head of a fowl or of a dissected bird, and find if there is a covering on the bill which can be cut or scraped off. Is the mass of the bill of bony or horny material? With what part of the human head are the mandibles homologous? (Fig. 284.)

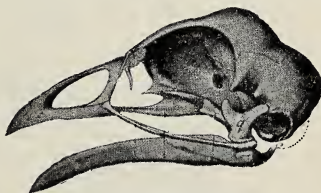


FIG. 284.—SKULL OF DOMESTIC FOWL.

*q*, quadrate ("four-sided") bone by which lower jaw is attached to skull (wanting in beasts, present in reptiles; see Fig. 277).

**Ears.**—Do birds have external ears? Is there an *external opening* leading to the ear? In searching for it, blow or push forward the feathers. If found, notice its location, size, shape, and what surrounds the opening. There is an owl spoken of as the long-eared owl. Are its ears long?

The **leg** has three divisions: the uppermost is the *thigh* (called the "second joint" in a fowl); the middle division is the *shank* (or "drumstick"); and the lowest, which is the slender bone covered with scales, is formed by the union of the *ankle* and the *instep*. (The bones of the three divisions are named femur, tibiotarsus, and tarsometatarsus.) The *foot* consists entirely of toes, the bones of which are called phalanges. Is there a bone in each claw? (See Fig. 285.) Supply the numerals in this sentence:

The pigeon has — toes, the hind toe having — joints; of the three front toes, the inner has — joints (count the claw as one joint), the

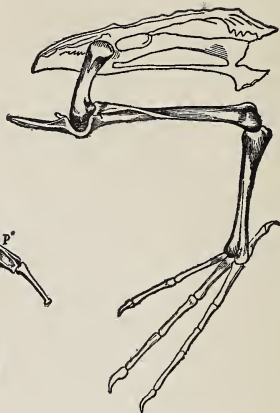


FIG. 285.—LEG BONES OF BIRD.

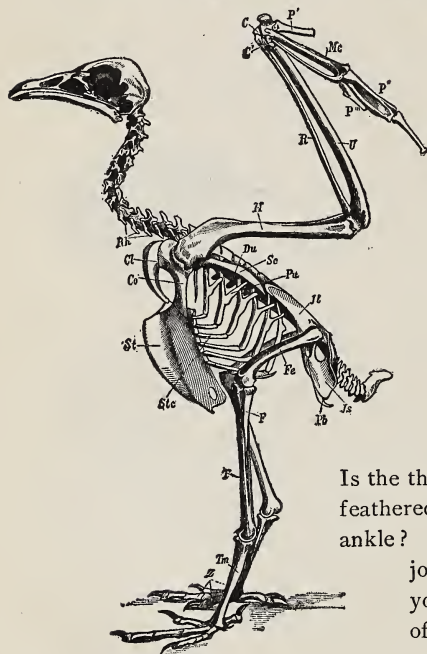


FIG. 286.—SKELETON OF BIRD.

*Rh*, vertebræ; *Cl*, clavicle; *Co*, coracoid; *Sc*, scapula; *St*, sternum; *H*, humerus; *R*, radius; *U*, ulna; *P*, thumb; *Fe*, femur; *T*, tibia. See Fig. 394.

**Questions:** Which is the stiffest portion of the vertebral column? How are the ribs braced against each other? Which is longer, thigh bone or shin? Compare shoulder blade with man's (Fig. 399). Which is the extra shoulder bone? Compare tail vertebræ with those of extinct bird, Fig. 290.

middle has — joints, and the outer toe has — joints (Fig. 285).

Is the thigh of a bird bare or feathered? The shin? The ankle? Where is the ankle joint of a bird? Do you see the remains of another bone (the splint bone, or fibula) on the shin bone of the shank? (Fig. 285 or 286.) Why would several joints in the ankle be a disadvantage to a bird?

The *thigh* hardly projects beyond the skin of the trunk, as may be noticed in a plucked fowl. The thigh extends forward from the hip joint (Figs. 286, 299) in order to bring the point of support forward under the centre of weight. Why are long front toes more necessary than long hind toes? As the bird must often bring its head to the ground, the hip joints are near the dorsal surface and the body swings between the two points of support somewhat like a silver ice pitcher on its two pivots. Hence stooping, which makes a man so unsteady, does not cause a bird to lose steadiness.

The *wing* has three divisions which correspond to the upper arm, the forearm, and the hand of man (Fig. 286). When the wing is folded, the three divisions lie close alongside one another. Fold your arm in the same manner. The similarity of the bones of the first and second divisions to the bones of our upper *arm* and *forearm* is very obvious (Fig. 286). Explain. The *hand* of a bird is furnished with only three digits (Fig. 287). The three palm bones (metacarpals) are firmly united (Fig. 287). This gives firmness to the stroke in flying.

That the bird is descended from animals which had the

fingers and palm bones less firmly united is shown by comparing the hands of a *chick* and of an *adult* fowl (Figs. 287, 288). The wrist also solidifies with age, the

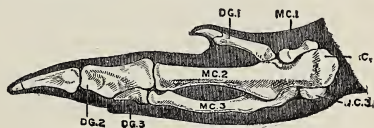


FIG. 287.—HAND AND WRIST OF FOWL (after Parker).

DG. 1-3, digits; MC. 1-3, metacarpals;  
CC. 3, wrist.

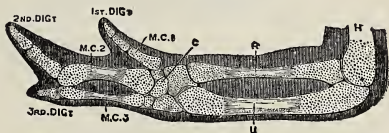


FIG. 288.—HAND, WRIST (C), FOREARM, AND ELBOW OF YOUNG CHICK (after Parker).

five carpals of the chick being reduced to two in the fowl (Figs. 287, 288). The thumb or first digit has a covering



FIG. 289. — BREAST-BONE AND SHOULDER BONES OF CASSOWARY.

of skin separate from that of the other digits, as may be seen in a plucked bird. The degenerate hand of the fowl is of course useless as a hand (what serves in its place?) but it is well fitted for firm support of the feathers in flying. The two bones of the forearm are also firmly joined. There are eighteen movable joints in our arm and hand. The bird has only the three joints which enable it to fold its wing. The wrist joint is

the joint in the forward angle of the wing.

Since the fore limbs are taken up with locomotion, the **grasping function** has been assumed by the *jaws*. How does their

shape adapt them to this use? For the same reason the *neck* of a bird surpasses the necks of all other animals in what respect? Is the trunk

of a bird

flexible or

inflexible?

There is

thus a *cor-*

*relation* between struc-

ture of neck and trunk.

Explain. The same

correlation is found in

which of the reptiles?

(Why does rigidity of

trunk require flexibility

of neck?) Why does

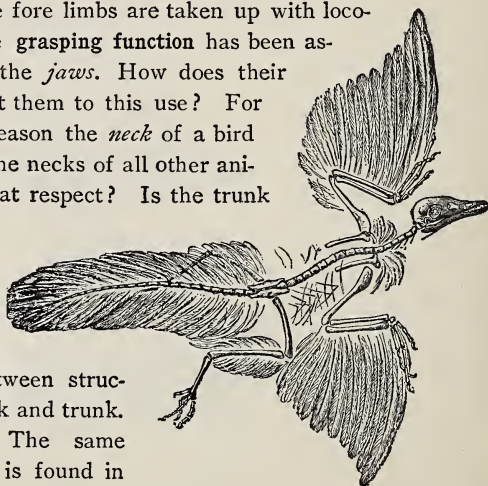


FIG. 290. — A FOSSIL BIRD (*archæopteryx*) found in the rocks of a former geological epoch.

Question: Find two resemblances to reptiles in this extinct bird absent from skeletons of extant birds.

the length of neck in birds correlate with the length of legs? Examples? (See Figs. 314, 315, 332.) Exceptions? (Fig. 324.) Why does a swan or a goose have a long neck, though its legs are short?

To make a firm support for the wings the vertebræ of the back are immovably joined, also there are three bones in each shoulder, the collar bone, the shoulder blade, and the coracoid bone (Fig. 286). The collar bones are united (why?) and form the "wishbone" or "pulling bone." To furnish surface for the attachment of the large flying muscles there is a prominent ridge or keel on the breastbone (Fig. 286). It is lacking in most birds which do not fly (Fig. 289).

The **feathers** are perhaps the most characteristic feature of birds. The large feathers of the wings and tail are called *quill feathers*. A quill feather (Fig. 291) is seen to consist of two parts, the *shaft*, or supporting axis, and the broad *vane* or web.

What part of the shaft is round? Hollow? Solid? Is the shaft straight? Are the sides of the vane usually equal in width? Can you tell by looking at a quill whether it belongs to the wing or the tail, and which wing or which side of the tail it comes from? Do the quills overlap with the wide side of the vane above or beneath the next feather? Can you cause two parts of the vane to unite again

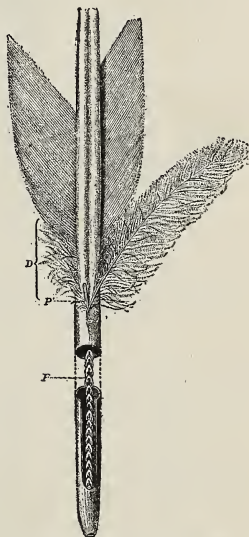


FIG. 291.—QUILL FEATHER  
D, downy portion.

by pressing together the two sides of a split in the vane? Does the web separate at the same place when pulled until it splits again?

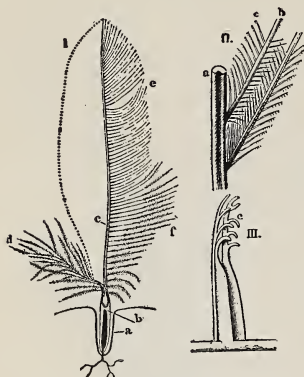


FIG. 292. — I, CONTOUR FEATHER. II, III, PARTS OF QUILL FEATHER, enlarged.

The hollow part of the shaft of a quill feather is called the *quill*. The part of the shaft bearing the vane is called the *rachis* (rā-kis). The vane consists of slender *barbs* which are branches of the shaft (II, Fig. 292). As the name indicates (see dictionary), a barb resembles a hair. The barbs in turn bear secondary branches called *barbules*, and these again have shorter branches called *barbicels* (III, Fig. 292). These are sometimes bent in the form of hooklets (Fig. 292, III), and the hooklets of neighbouring barbules interlock, giving firmness to the vane. When two barbules are split apart, and then reunited by stroking the vane between the thumb and the finger, the union may be so strong that a pull upon the vane will cause it to split in a new place next time.

There are **four kinds** of feathers, (1) the *quill* feathers, just studied; (2) the *contour* feathers (I, Fig. 292), which form the general surface of the body and give it its outlines; (3) the *downy* feathers (Fig. 293), abundant on



FIG. 293. — A DOWN FEATHER, enlarged.



nestlings and found among the contour feathers of the adult but not showing on the surface ; (4) the *pin* feathers, which are hair-like, and which are removed from a plucked bird by singeing. The contour feathers are similar in structure to the quill feathers. They protect the body from blows, overlap so as to shed the rain, and, with the aid of the downy feathers, retain the heat, thus accounting for the high temperature of the bird. The downy feathers are soft and fluffy, as they possess few or no barbicels; sometimes they lack the rachis (Fig. 293). The pin feathers are delicate horny shafts, greatly resembling hairs, but they may have a tuft of barbs at the ends.

A feather grows from a small projection (or papilla) found at the bottom of a depression of the skin. The quill is formed by being moulded around the papilla. Do you see any opening at the tip of the quill for blood-vessels to enter and nourish the feather? What is in the quill? (Fig. 291.) The rachis? A young contour or quill feather is inclosed in a delicate sheath which is cast off when the feather has been formed. Have you seen the sheath incasing a young feather in a moulting bird?

There are considerable areas or tracts on a bird's skin without contour feathers. Such bare tracts are

found along the ridge of the breast and on the sides of the neck. However, the contour feathers lie so as to overlap and cover the whole body perfectly (Fig. 294).

The shedding of the feathers is called moulting. Feathers,

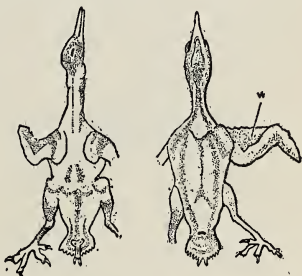


FIG. 294.—DORSAL AND VENTRAL VIEW OF PLUCKED BIRD, showing regions where feathers grow.

like the leaves of trees, are delicate structures and lose perfect condition with age. Hence the annual renewal

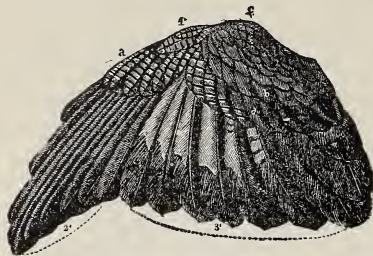


FIG. 295. — WING OF BIRD.

*z*, false quills (on thumb); *z*, primaries; *3*, secondaries; tertiaries (dark) are one above another at right; *a*, *b*, coverts.

always shed with it. (What need for this?) A large *oil gland* is easily found on the dorsal side of the tail. How does the bird apply the oil to the feathers?



FIG. 296.

*A*, point dividing primaries from secondaries; *B*, coverts.

In describing and classifying birds, it is necessary to know the names of the various external **regions** of the body and plumage. These may be learned by studying Figs. 295, 296, 297, 298.

of the feathers is an advantage. Most birds shed twice a year, and with many the summer plumage is brighter coloured than the winter plumage. When a feather is shed on one side, the corresponding feather on the other side is

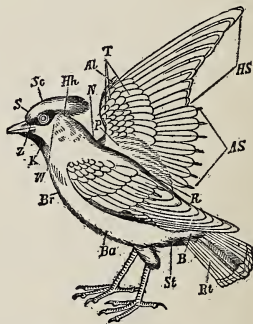


FIG. 297. — CEDAR WAXWING, with regions of body marked.

*S*, forehead; *Sc*, crown (with crest); *Hh*, nape; *K*, throat; *Br*, breast; *Ba*, lower parts; *R*, back; *Rt*, tail; *B*, tail coverts; *P*, shoulder feathers (scapulars); *T*, wing coverts; *HS*, primaries; *AS*, secondaries; *Al*, thumb feathers.

The quills on the hand

are called primaries, those on the forearm are the secondaries, those on the upper arm are the tertiaries. Those on the tail are called the *tail quills*. The feathers at the base of the quills are called the *coverts*. The thumb bears one or more quills called the spurious quills. Is the wing concave on the lower or the upper side? Of what advantage is this when the bird is at rest? When it is flying?

**Control of Flight.** — Did you ever see a bird sitting on a swinging limb? What was its chief means of balancing itself? When flying, what does a bird do to direct its course upward? Downward? Is the body level when it turns to either side? Birds with long, pointed wings excel in what respect? Examples? Birds with great wing surface excel in what kind of flight? Examples. Name a common bird with short wings which has a laboured, whirring flight. Is its tail large or small?

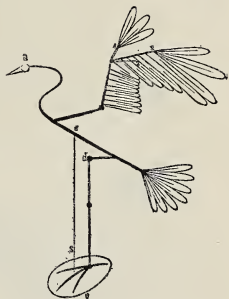


FIG. 298. — PLAN OF BIRD.  
s, centre of gravity.



FIG. 299. — POSITION OF  
LIMBS OF PIGEON.

Does it avoid obstacles and direct its flight well? Why or why not? When a boat is to be turned to the right, must the rudder be pulled to the right or to the left? (The rudder drags in the water and thus pulls the boat around.) When the bird wishes to go upward, must its tail be turned up or down? How when it wishes to go

down? When a buzzard soars for an hour without flapping its wings, does it move at a uniform rate? For what does it use the momentum gained when going with the wind?

**Flying.** — When studying the quill feathers of the wing, you saw that the wider side of the vane is beneath the feather next behind it. During the downward stroke of the wing this side of the vane is pressed by the air against

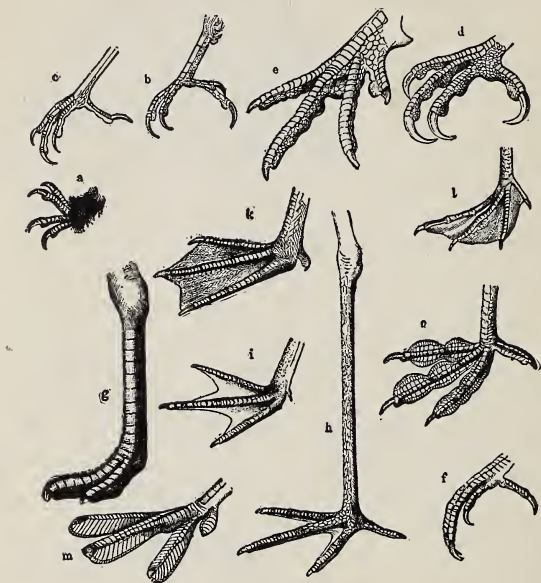


FIG. 300.

*a*, clambering foot of chimney sweep; *b*, climbing foot of woodpecker; *c*, perching foot of thrush; *d*, seizing foot of hawk; *e*, scratching foot of pheasant; *f*, stalking foot of kingfisher; *g*, running foot of ostrich; *h*, wading foot of heron; *i*, paddling foot of gull; *j*, swimming foot of duck; *k*, steering foot of cormorant; *l*, diving foot of grebe; *m*, skimming foot of coot. **Question:** Does any bird use its foot as a hand? (Fig. 320.)

the feather above it, and the air cannot pass through the wing. As the wing is raised the vanes separate and the air passes through. The convex upper surface of the wing also prevents the wing from catching air as it is raised. Spread a wing and blow strongly against

its lower surface; its upper surface. What effects are noticed?

Study the **scales** on the leg of a bird (Fig. 300). Why is the leg scaly rather than feathered from the ankle downward? Which scales are largest? (Fig. 300.) How do the scales on the front and the back differ? What can you say of the scales at the bottom of the foot; at the joints of the toes? Explain. How does the covering of the nails and the bill compare in colour, texture, hardness, and firmness of attachment with the scales of the leg?

**Draw** an outline of the bird seen from the side. Make drawings of the head and the feet more detailed and on a larger scale.

Why does a goose have more feathers suitable for making pillows than has a fowl? In what country did the domestic fowl originate? (Encyclopædia.) Why does a cock crow for dawn? (Consider animal life in jungle.)

**Activities of a Bird.** — Observe a bird *eating*. Does it seem to chew or break its food before swallowing? Does it have to lift its head in order to swallow food? To swallow drink? Why is there a difference? After feeding the bird, can you feel the food in the crop, or enlargement of the gullet at the base of the neck? (Fig. 304.)

Feel and look for any move-



FIG. 301. — AN ALTRICAL BIRD, *i.e.* poorly developed at hatching. Young pigeon, naked, beak too weak for eating.

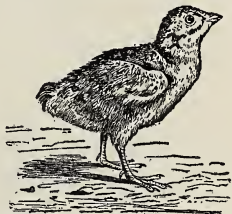


FIG. 302. — A PRECOCIAL BIRD (well developed at hatching). Feathered, able to run and to pick up food. Precocity is a sign of instinctive life and low intelligence. A baby is not precocious.

Question: Is pigeon or fowl exposed to more dangers in infancy?

ments in *breathing*. Can you find how often it breathes per minute? Place hand under the bird's wing. What do you think of its *temperature*; or better, what temperature is shown by a thermometer held under its wing? Do you see any connection between the breathing rate and the temperature? Test (as with the crayfish) whether a bird can *see* behind its head? Notice the movements of the nictitating membrane. Does it appear to be transparent?

Watch a bird *fly* around a closed room and review the questions on Control of Flight.

*Bend* a bird's leg and see if it has any effect upon its toes. Notice a bird (especially a large fowl) walk, to see if it bends its toes as the foot is lifted. Pull the rear tendon in a foot cut from a fowl for the kitchen. Does the bird have to use muscular exertion to *grasp* a stick upon which it sits? Why, or why not? When is this bending of the toes by bending the legs of special advantage to a hawk? To a duck? To a wading bird? Why is a fowl safe from a hawk if it stands close to a tree?

Do you see any signs of teeth in the bird's jaws? Why are duck's "teeth" (so called by children) not teeth?

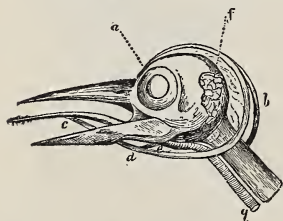


FIG. 303. — HEAD OF WOODPECKER.

*c*, tongue; *a*, *b*, *d*, hyoid bone; *e*, *g*, windpipe; *f*, salivary gland.

Can the tongue of a bird be pulled forward? (Fig. 303.) What is its shape? If there is opportunity, dissect and study the slender, bony (hyoid) apparatus to which the base of the tongue is attached (Fig. 303), the opening of the windpipe, or trachea, the slit-like opening

of windpipe, which is so narrow as to prevent food falling into the windpipe.



**The Internal Organs, or Viscera** (Figs. 304 and 305). — The viscera (*vis'se-ra*), as in most vertebrates, *include* the food tube and its glands; the lungs, the heart, and the larger blood vessels; the kidneys and bladder and the reproductive organs. The lower part, or gullet, is enlarged into a *crop*. It is largest in grain-eating birds. It

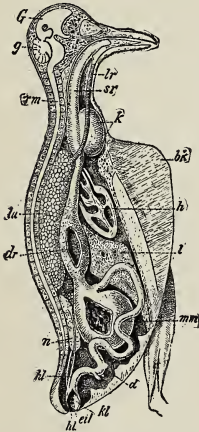


FIG. 304. — ANATOMY OF DOVE  $\times \frac{1}{2}$ .

*bk*, keel of breastbone; *G*, *g*, brain; *lr*, windpipe; *lu*, lung; *h*, heart; *sr*, gullet; *k*, crop; *dr*, glandular stomach; *mm*, gizzard; *d*, intestine; *n*, kidney; *hl*, ureter; *cil*, openings of ureter and egg duct into cloaca, *kl*.

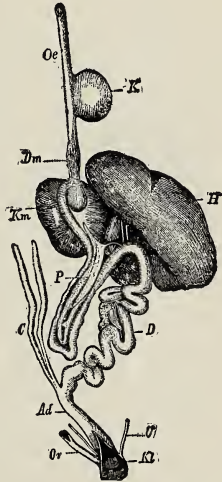


FIG. 305. — FOOD TUBE OF BIRD.

*P*, pancreas; *C*, caeca.

**Question:** Identify each part by means of Fig. 304.

is found in the V-shaped depression at the angle of the wishbone, just before the food tube enters the thorax. The food is stored and softened in the crop. From the crop the food passes at intervals into the glandular stomach. Close to this is the muscular stomach, or gizzard. Are the places of entrance and exit on opposite sides of the gizzard, or near together? (Fig. 304.) Is the lining of the gizzard

rough or smooth? Why? Is the gizzard tough or weak? Why are small stones in the gizzard? Why do not hawks and other birds of prey need a muscular gizzard? The liver and pancreas empty their secretions into the intestines by several ducts a little way beyond the gizzard. Beyond the mouths of two cæca (Fig. 305) the many-coiled

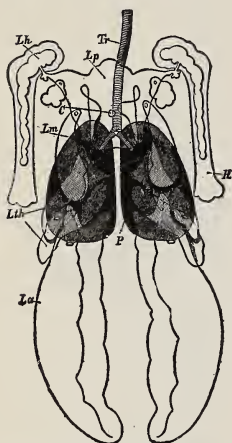


FIG. 306.—POSITION OF LUNGS AND AIR SACS (Pigeon).

Tr, windpipe; P, lungs; Lm, sac under clavicle with prolongation (Lh) into humerus; La, sacs in abdomen.

intestine empties into the straight rectum, which terminates in a widened part called the cloaca. Not only the intestine, but the two ureters of the urinary system and the two genital ducts of the reproductive system all empty into the cloaca (Figs. 304, 305).

The lungs have their rear surfaces attached to the spinal column and ribs (lu, Fig. 304). They are connected with thin-walled, transparent *air sacs* which aid in purifying the blood. When inflated with warm air, they probably make the body of the bird more buoyant. For the names, location, and shape of several pairs of air sacs, see Fig. 306.

The connection of the air sacs with hollows in the humerus bones is also shown in the figure. Many of the *bones are hollow*; this adds to the buoyancy of the bird. The pulmonary artery, as in man, takes dark blood to the lungs to exchange its carbon dioxide for oxygen. Of two animals of the same weight, which expends more energy, the one that flies, or the one that runs the same distance? Does a bird require more oxygen

or less, in proportion to its weight, than an animal that lives on the ground? Are the vocal chords of a bird higher or lower in the wind-pipe than those of a man? (Fig. 307.)

The heart of a bird, like a man's heart, has four chambers; hence it keeps the purified blood separate from the impure blood. Since pure blood reaches the organs of a bird, oxidation is more perfect than in the body of any animals yet studied. Birds have higher

temperature than any other class of animals whatsoever. Tell how the jaws, the tail, and the wings of the fossil bird *Archæopteryx* differed from living birds (Fig. 290).

**SUGGESTIONS.**—In the field work, besides seeking the answers to definite questions, pupils may be required to hand in a record of the places and the times of seeing a certain number of birds (20-40) with the actions and features which made each distinguishable. Also, and more important, each pupil should hand in a record of a careful and thorough outdoor study of one common species (see below) as regards habits, nesting, relation to environment, etc.

**Field Study of a Common Species.**— (*For written report.*) Name of species. *Haunts*. Method of locomotion when not flying. *Flying* (rate, sailing, accompanying sound if any, soaring).

What is the *food*? How obtained? *Association* with birds of its own species. *Relation* to birds of other species.

Where does it build its *nest*? Why is such a situation selected? Of what is the nest built? How is the material carried, and how built into the nest? Does the bird's body fill the nest?

Describe the *eggs*. Does the male bird ever sit or otherwise assist female before hatching? Does it assist after hatching?

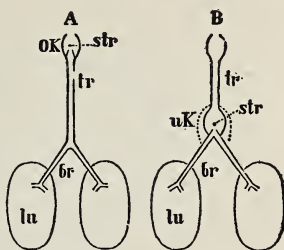


FIG. 307. — POSITION OF VOCAL CORDS (*str*) OF MAMMAL AND BIRD.

**Question:** Does a fowl ever croak after its head and part of its neck are cut off? Explain.

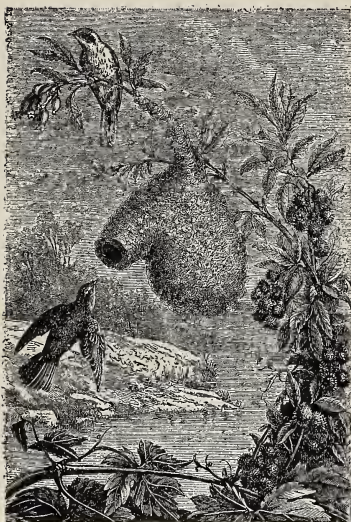


FIG. 308. — EUROPEAN TOMTIT'S NEST.

What are the advantages of its shape?

fore they leave the nest? Do the parents try to teach them to fly? Do the parents care for them after the nest is left? What songs or calls has the bird?

### General Field Study.

—(*For written report.*)

Name the best and poorest flyers you know; birds that fly most of the time; birds that seldom fly. Observe birds that pair; live in flocks. Does their sociability vary with the season? Do you ever see birds quarrelling?

How long is taken to lay a sitting of eggs? How long before the birds are hatched? *When hatched* are they helpless? Blind? Feathered? (Figs. 301, 302.) Do the nestlings require much food? How many times in an hour is food brought? How distributed? Even if the old birds sometimes eat fruit do they take fruit to the young? What do they feed to the young? How long be-



FIG. 309. — TAILOR BIRD'S NEST (India).

Instinct for nest building highly perfected.

Fighting? What birds do you observe whipping or driving birds larger than themselves? Which parent do young birds most resemble? Name the purposes for which birds sing. Which senses are very acute? Why? Dull? Why? Can you test your statements by experiment? A partridge usually sits with 18 to 24 eggs in nest. About how long after laying first egg before sitting begins? Do several partridge hens lay in the same nest?



FIG. 310.—HOUSE WREN.

*Haunts.*—Name some birds that are found most often in the following localities: about our homes, in gardens and orchards, fields and meadows, in bushes, in the woods, in secluded woods, around streams of water, in thickets, in pine woods.

*Size.*—Name birds as large as a robin or larger, nearly as large, half as large, much smaller.

*Colours.*—Which sex is more brilliant? Of what advantage are bright colours to one sex? Of what advantage are dull colours to the other sex? Which have yellow breasts, red patch on heads, red or chestnut breasts, blue backs, black all over?

*Habits.*—Name the birds that walk, jump, swim, live in flocks, sing while flying, fly in undulations, in circles, have laboured flight.

**Economic Importance of Birds.**—Farmers find their most valuable allies in the class *aves*, as birds are the deadliest enemies of insects and gnawing animals. To the innumerable robbers which devastate our fields and gardens, nature opposes the army of birds. They are less numerous





FIG. 311. — SCREECH OWL (*Megascops asio*).

**Question:** Compare posture of body, position of eyes, and size of eyes, with other birds.

(and those of the day to a less degree) are very destructive to field-mice, rabbits, and other gnawing animals. Some ignorant farmers complain continually about the harm done by birds. To destroy them is as unwise as it would be to destroy the skin which protects the human body because it has a spot upon it! It cannot be repeated too plainly that to hunt useful birds is a wrong and mischievous act, and it is stupid and barbarous to destroy their nests.

Injurious birds are few. Of course birds which are the enemies of other birds are enemies

than insects and other robbers, it is true, but they are skilful and zealous in pursuit, keen of eye, quick, active, and remarkably voracious. The purely insectivorous birds are the most useful, but the omnivorous and graminivorous birds do not disdain insects. *The perchers and the woodpeckers should be protected most carefully.*

The night birds of prey



FIG. 312. — GOSHAWK, or chicken hawk.



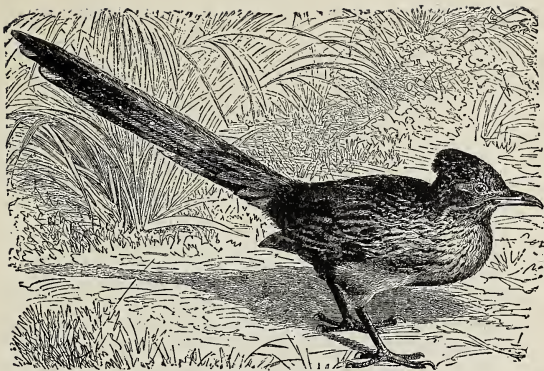


FIG. 313. — ROAD RUNNER, or chaparral bird (Tex. to Cal.). What order?  
(Key, p. 177.)

of mankind, but examples are scarce (some owls and hawks). Many birds of prey are classed thus by mistake. Sparrow-hawks, for instance, do not eat birds except in rare instances; they feed chiefly upon insects. A sparrow-hawk often keeps watch over a field where grasshoppers are plentiful and destroys great numbers of them. When a bird is killed because it is supposed to be injurious, the crop should always be examined, and its contents will often surprise those who are sure it is a harmful bird. The writer once found two frogs, three grasshoppers, and five beetles that had been swallowed by a "chicken hawk" killed by an irate farmer, but no sign of birds having been used for food. Fowls should not be raised in open places, but among trees and bushes, where hawks cannot swoop. Birds which live exclusively upon fish are, of course, opposed to human interests. Pigeons are destructive to grain; eagles feed chiefly upon other birds.

If the birds eat the grapes, do not kill the birds, but plant more grapes. People with two or three fruit trees or a small

garden are the only ones that lose a noticeable amount of food. We cut down the forests from which the birds obtain part of their food. We destroy insect pests at great cost of spraying, etc. The commission the birds charge for such work is very small indeed. (See pages 177-183.)



FIG. 314.—WOOD DUCK, male (*Aix sponsa*). Nests in hollow trees throughout North America. Also called summer duck in South. Why?

The **English sparrow** is one bird of which no good word may be said. Among birds, it holds the place held by rats among beasts. It is crafty, quarrelsome, thieving, and a nuisance. It was imported in 1852 to eat moths. The results show how ignorant we are of animal life, and how slow we should be to tamper with the arrangements of nature. In Southern cities it produces five or six broods each year with four to six young in each brood. (Notice what it feeds its young.) It fights, competes with, and drives away our native useful birds. It also eats grain and preys upon gardens. They have multiplied more in Aus-

tralia and in North America than in Europe, because they left behind them their native enemies and their new enemies (crows, jays, shrikes, etc.) have not yet developed, to a sufficient extent, the habit of preying upon them. Nature will, perhaps, after a long time, restore the equilibrium destroyed by presumptuous man.

**Protection of Birds.**—1. Leave as many trees and bushes standing as possible. Plant trees, encourage bushes.

2. Do not keep a cat. A mouse trap is more useful than a cat. A tax should be imposed upon owners of cats.

3. Make a bird house and place it on a pole; remove bark from pole that cats may not climb it; or put a broad band of tin around the pole.

4. Scatter food in winter. In dry regions and in hot weather keep a shallow tin vessel containing water on the roof of an outhouse, or in an out-of-the-way place, for shy birds.

5. Do not wear feathers obtained by the killing of birds. What feathers are not so obtained?

6. Report all violators of laws for protection of birds.

7. Destroy English sparrows.

**Migration.**—Many birds, in fact most birds, migrate to warmer climates to spend the winter. Naturalists were

once content to speak of the migration of birds as a wonderful instinct,

and made no attempt to explain it. As

birds have the warmest covering of all animals, the winter migration is not for the purpose of escaping the cold; it

is probably to escape starvation, because in cold countries food is largely hidden by snow in winter. On the other hand, if the birds remained

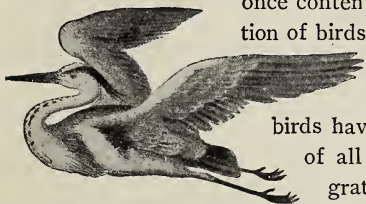


FIG. 315. — GREAT BLUE HERON.

In flight, balancing with legs.

in the warm countries in summer, the food found in northern countries in summer would be unused, while they would have to compete with the numerous tropical birds for food, and they and their eggs would be in danger from snakes, wild cats, and other beasts of prey so numerous in warm climates. These are the best reasons so far given for migration.

The **manner and methods of migration** have been studied more carefully in Europe than in America. Migration is

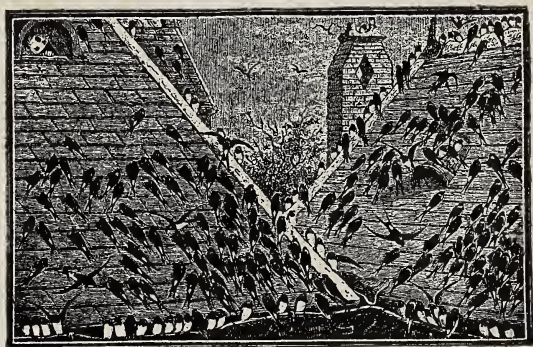


FIG. 316.—EUROPEAN SWALLOWS (*Hirundo urbana*), assembling for autumn flight to South.

not a blind, infallible instinct, but the route is learned and taught by the old birds to the young ones; they go in flocks to keep from losing the way (Fig. 316); the oldest and strongest birds guide the flocks (Fig. 317). The birds which lose their way are young ones of the last brood, or mothers that turn aside to look for their strayed young. The adult males seldom lose their way unless scattered by a storm. Birds are sometimes caught in storms or join flocks of another species and arrive in countries unsuited for them, and perish. For example, a sea or

marsh bird would die of hunger on arriving in a very dry country.

The landmarks of the route are mountains, rivers, valleys, and coast lines. This knowledge is handed down from one generation to another. It includes the location of certain places on the route where food is plentiful and the birds can rest in security. Siebohm and others have studied

the routes of migration in the Old World. The route from the nesting places in northern Europe to

Africa follows the Rhine, the Lake of Geneva, the Rhone, whence some species follow the Italian and others the Spanish coast-line to Africa. Birds choose the lowest mountain passes. The Old World

martin travels every year from the North Cape to the Cape of Good Hope and back again! Another route has been traced from Egypt along the coast of Asia Minor, the Black Sea and Ural Mts. to Siberia.

**Field Study of Migration.** — Three columns may be filled on the blackboard in an unused corner, several months in spring or fall being taken for the work. *First* column, birds that stay all the year. *Second* column, birds that come from the south and are seen in summer only. *Third* column, birds that come from the north and are seen in winter only. Exact dates of arrival and departure and flight overhead should be recorded in notebooks. Many such records will enable American zoologists to trace the migration routes of our birds.

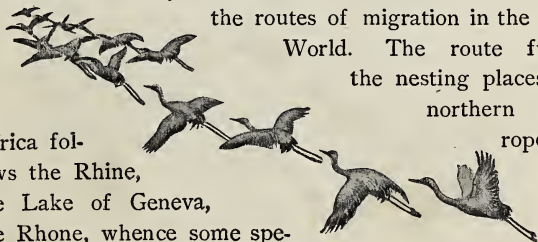


FIG. 317. — CRANES MIGRATING, with leader at point of V-shaped line.



**Moulting.**—How do birds arrange their feathers after they have been ruffled? Do they ever bathe in water?

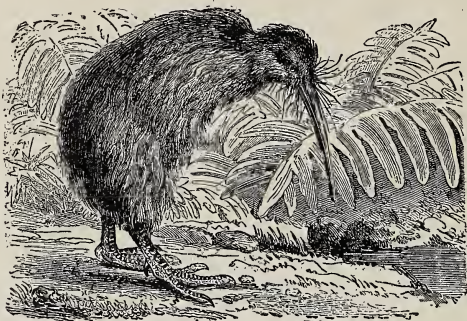


FIG. 318. — *APTERYX*, of New Zealand. Size of a hen, wings and tail rudimentary, feathers hair-like.

In dust? Dust helps to remove old oil. At what season have birds the brightest feathers? Why? Have you ever

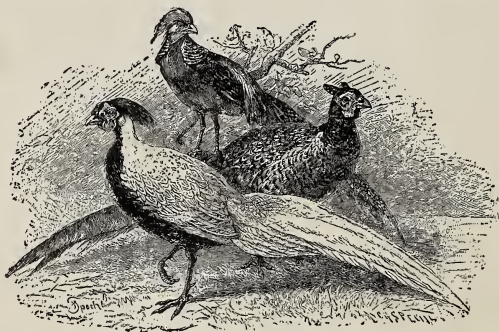


FIG. 319. — *GOLDEN, SILVER, AND NOBLE PHEASANTS*, males. Order? (Key, p. 177.) Ornaments of males, brightest in season of courtship, are due to sexual selection (Figs. 321-7-9, 333).

seen evidence of the moulting of birds? Describe the moulting process (page 120).



### Adaptations for

**Flying.** — Flight is the most difficult and energy-consuming method of moving found among animals, and careful adjustment is necessary. For balancing, the heaviest muscles are placed at the lower and central portion of the body. These are the flying muscles, and in some birds (humming birds) they make half of the entire weight. Teeth are the densest of animal structures; teeth and the strong chewing muscles required would make the head heavy and balancing difficult; hence the chewing apparatus is transferred to the heavy gizzard near the centre of gravity of the body. The bird's neck is long and excels all other necks in flexibility, but it is very slender (although apparently heavy), being inclosed in a loose, feathered skin. A cone is the best



FIG. 320.  
COCKATOO.

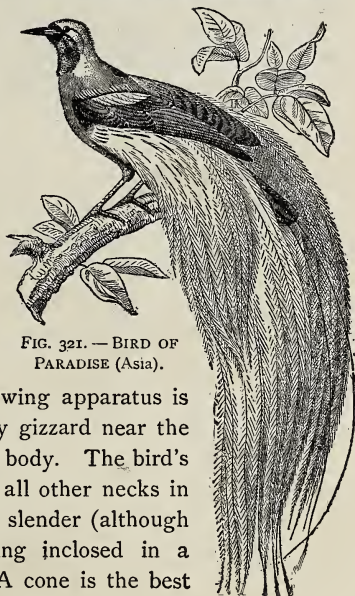


FIG. 321. — BIRD OF  
PARADISE (Asia).

shape to enable the body to penetrate the air, and a small neck would destroy the conical form. The internal organs are compactly arranged and rest in the cavity of the breast-bone. The bellows-like air sacs filled with warm air lighten the bird's weight. The bones are hollow and very thin. The large tail quills are used by the bird only in guiding its flight up and down, or balancing on a limb.

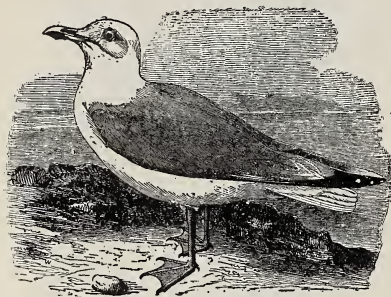


FIG. 322. — HERRING GULL. (Order?)

The feet also aid a flying bird in balancing. The wing is so constructed as to present to the air a remarkably large surface compared with the small bony support in the wing skeleton. Are tubes ever resorted to by

human architects when lightness combined with strength is desired? Which quills in the wing serve to lengthen it? (Fig. 296.) To broaden it? Is flight more difficult for a bird or for a butterfly? Which of them do the flying machines more closely resemble? Can any bird fly for a long time without flapping its wings?

**Exercise in the Use of the Key.** — Copy this list and write the name of the order to which each of the birds belongs. (Key, page 177.)

Cockatoo (Fig. 320)	Wren (Fig. 310)	Pheasant (Fig. 319)
Sacred Ibis (Fig. 328)	Apteryx (Fig. 318)	Wood Duck (Fig. 314)
Screech Owl (Fig. 311)	Lyre bird (Fig. 327)	Jacana (Fig. 324)
Nightingale (Fig. 325)	Road Runner (Fig. 313)	Sea Gull (Fig. 322)
Top-knot Quail (Fig. 329)	Ostrich (Fig. 332)	Heron (Fig. 315)
	Penguin (Fig. 330)	Hawk (Fig. 312)

KEY, OR TABLE, FOR CLASSIFYING BIRDS (*Class Aves*)  
INTO ORDERS

## ORDERS

A <sub>1</sub> Wings not suited for flight, 2 or 3 toes	RUNNERS
A <sub>2</sub> Wings suited for flight (except the penguin)	
B <sub>1</sub> Toes united by a web for swimming, legs short	
C <sub>1</sub> Feet placed far back; wings short, tip not reaching to base of tail (Fig. 300)	DIVERS
C <sub>2</sub> Bill flattened, horny plates under margin of upper bill (Fig. 323)	BILL-STRAINERS
C <sub>3</sub> Wings long and pointed, bill slender	SEA-FLIERS
C <sub>4</sub> All four toes webbed, bare sac under throat	GORGERS
B <sub>2</sub> Toes not united by web for swimming	
C <sub>1</sub> Three front toes, neck and legs long, tibia (shin, or "drumstick") partly bare	WADERS
C <sub>2</sub> Three front toes, neck and legs not long	
D <sub>1</sub> Claws short and blunt (e, Fig. 300)	
E <sub>1</sub> Feet and beak stout, young feathered, base of hind toe elevated	SCRATCHERS
E <sub>2</sub> Feet and beak weak, young naked	MESSENGERS
D <sub>2</sub> Claws long, curved and sharp, bill hooked and sharp	ROBBERS
D <sub>3</sub> Claws long, slightly curved, bill nearly straight	PERCHERS
C <sub>3</sub> Two front and two hind toes (Fig. 300)	
D <sub>1</sub> Bill straight, feet used for climbing	FOOT-CLIMBERS
D <sub>1</sub> Bill hooked, both bill and feet used for climbing	BILL-CLIMBERS

**The Food of Birds.** — Extracts from Bulletin No. 54 (United States Dept. of Agriculture), by F. E. L. Beal.

The practical value of birds in controlling insect pests should be more generally recognized. It may be an easy matter to exterminate the birds in an orchard or grain field, but it is an extremely difficult one to control the insect pests. It is certain, too, that the value of our native sparrows as weed destroyers is not appreciated. Weed seed forms an important item of the winter food of many of these birds, and it is impossible to estimate the immense numbers of noxious weeds which are thus annually

destroyed. If crows or blackbirds are seen in numbers about cornfields, or if woodpeckers are noticed at work in an orchard,



FIG. 323. — HEAD OF DUCK.

it is perhaps not surprising that they are accused of doing harm. Careful investigation, however, often shows that they are actually destroying noxious insects; and also that even those which do harm at one season may compensate for it by eating insect pests at another.

Insects are eaten at all times by the majority of land birds. During the breeding season most kinds subsist largely on this food, and rear their young exclusively upon it.

**Partridges.** — Speaking of 13 birds which he shot, Dr. Judd says: These 13 had taken weed seed to the extent of 63 per cent of

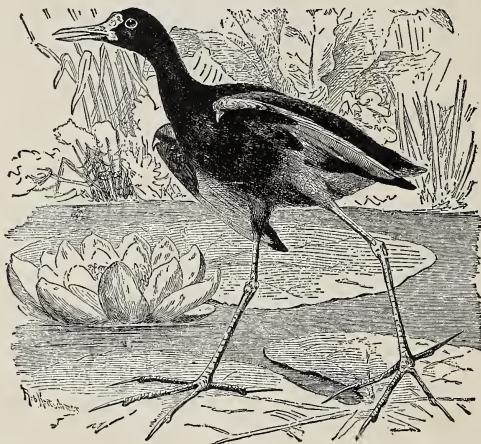


FIG. 324. — JACANA. (Mexico, Southwest Texas, and Florida.)

**Questions:** What appears to be the use of such long toes? What peculiarity of wing? head?

their food. Thirty-eight per cent was ragweed, 2 per cent tick trefoil, partridge pea, and locust seeds, and 23 per cent seeds of miscellaneous weeds. About 14 per cent of the quail's food for

the year consists of animal matter (insects and their allies). Prominent among these are the Colorado potato beetle, the striped squash beetle, the cottonboll-weevil, grasshoppers. As a weed destroyer the quail has few, if any, superiors. Moreover, its habits are such that it is almost constantly on the ground, where it is brought in close contact with both weed seeds and ground-living insects. It is a good ranger, and, if undisturbed, will patrol every day all the fields in its vicinity as it searches for food.



FIG. 325.—NIGHTINGALE,  $\times \frac{1}{2}$ .



FIG. 326.—SKYLARK,  $\times \frac{1}{2}$ .

Two celebrated European songsters.

**Doves.**—The food of the dove consists of seeds of weeds, together with some grain. The examination of the contents of 237 stomachs shows that over 99 per cent of the food consists wholly of vegetable matter.

**Cuckoos.**—An examination of the stomachs of 46 black-billed cuckoos, taken during the summer months, showed the remains of 906 caterpillars, 44 beetles, 96 grasshoppers, 100 sawflies, 30 stink bugs, and 15 spiders. Of the yellow-billed cuckoos, or "rain-crow," 109 stomachs collected from May to October, inclusive, were examined. The contents consisted of 1,865 caterpillars, 93 beetles, 242 grasshoppers, 37 sawflies, 69 bugs, 6 flies, and 86 spiders.



**Woodpeckers.** — Careful observers have noticed that, excepting a single species, these birds rarely leave any conspicuous mark on a healthy tree, except when it is affected by wood-boring larvæ, which are accurately located, dislodged, and devoured by the woodpecker. Of the flickers' or yellow-hammers' stomachs examined, three were completely filled with ants. Two of the birds each contained more than 3,000 ants, while the third bird contained fully 5,000. These ants belong to species which live in the ground. It is these insects for which the flicker is reaching when it runs about in the grass. The yellow-bellied woodpecker or sapsucker (*Sphyrapicus varius*) was shown to be guilty of pecking holes in the bark of various forest trees, and sometimes in that of apple



FIG. 327. — LYRE BIRD, male.

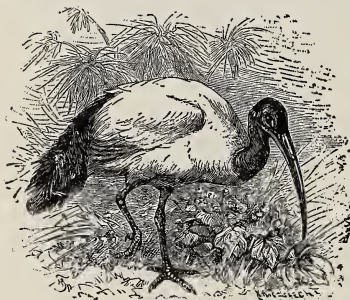


FIG. 328. — SACRED IBIS. (Order?)

trees, and of drinking the sap when the pits became filled. It has been proved, however, that besides taking the sap the bird captures large numbers of insects which are attracted by the sweet fluid, and that these form a very considerable portion of its diet. The woodpeckers seem the only agents which can successfully

cope with certain insect enemies of the forests, and, to some extent, with those of fruit trees also. For this reason, if for no other, they should be protected in every possible way.



The night hawk, or "bull bat," may be seen most often soaring high in air in the afternoon or early evening. It nests upon rocks or bare knolls and flat city roofs. Its food consists of insects taken on the wing; and so greedy is the bird that when food is plentiful, it fills its stomach almost to bursting. Ants (except workers) have wings and fly as they are preparing to propagate. In destroying ants night hawks rank next to, or even with, the woodpeckers, the acknowledged ant-eaters among birds.



FIG. 329. — TOP-KNOT QUAIL, or California Partridge.  
(West Texas to California.)

The kingbird, or martin, is largely insectivorous. In an examination of 62 stomachs of this bird, great care was taken to identify every insect or fragment that had any resemblance to a honeybee; as a result, 30 honeybees were identified, of which 29 were males or drones and 1 was a worker.

Blue Jay. — In an investigation of the food of the blue jay 300 stomachs were examined, which showed that animal matter comprised 24 per cent and vegetable matter 76 per cent of the bird's diet. The jay's favourite food is mast (*i.e.* acorns, chestnuts, chinquapins, etc.), which was found in 200 of the 300 stomachs, and amounted to more than 42 per cent of the whole food.

**Crow.** — That he does pull up sprouting corn, destroy chickens, and rob the nests of small birds has been repeatedly proved. Nor are these all of his sins. He is known to eat frogs, toads, salamanders, and some small snakes, all harmless creatures that do some good



FIG. 330. — PENGUIN OF PATAGONIA. Wings used as flippers for swimming.

by eating insects. Experience has shown that they may be prevented from pulling up young corn by tarring the seed, which not only saves the corn but forces them to turn their attention to insects. May-beetles, "dor-bugs," or June bugs, and others of the same family constitute the principal food during spring and early summer, and are fed to the young in immense quantities.

**Rice-bird.** — The annual loss to rice growers on account of bobolinks has been estimated at \$2,000,000.

**Meadow Lark.** — Next to grasshoppers, beetles make up the most important item of the meadow lark's food, amounting to nearly 21 per cent. May is the month when the dreaded cut worm begins its deadly career, and then the lark does some of its best work. Most of these caterpillars are ground feeders, and are overlooked by birds which habitually frequent trees, but the meadow lark finds and devours them by thousands.



FIG. 331. — Umbrella holding the nests of social weaver bird of Africa; polygamous.

**Sparrows.** — Examination of many stomachs shows that in winter the tree sparrow feeds entirely upon seeds of weeds. Probably each bird consumes about one fourth of an ounce a day. Farther south the tree sparrow is replaced in winter by the white-throated sparrow, the white-crowned sparrow, the fox sparrow, the song sparrow, the field sparrow, and several others; so that all over the land a vast number of these seed eaters are at

work during the colder months reducing next year's crop of worse than useless plants.

**Robin.**—An examination of 500 stomachs shows that over 42 per cent of its food is animal matter, principally insects, while the remainder is made up largely of small fruits or berries. Vegetable food forms nearly 58 per cent of the stomach contents, over 47 per cent being wild fruits, and only a little more than 4 per cent being possibly cultivated varieties. Cultivated fruit amounting to about 25 per cent was found in the stomachs in June and July, but only a trifle in August. Wild fruit, on the contrary, is eaten in every month, and constitutes during half the year a staple food.

**Questions.**—Which of these birds are common in your neighbourhood? Which of them according to the foregoing report are plainly injurious? Clearly beneficial? Doubtful? Which are great destroyers of weed seeds? Wood-borers? Ants? Grain? Why is the destruction of an ant by a night hawk of greater benefit than the destruction of an ant by a woodpecker? Name the only woodpecker that injures trees. If a bird eats two ounces of grain and one ounce of insects, has it probably done more good or more evil?

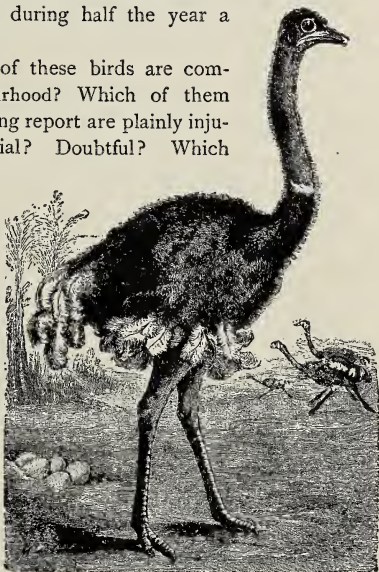


FIG. 332.—AFRICAN OSTRICH,  $\times \frac{1}{20}$ . (Order?)

## CHAPTER XIV

### MAMMALS

**SUGGESTIONS.** — A tame rabbit, a house cat, or a pet squirrel may be taken to the school and observed by the class. Domestic animals may be observed at home and on the street. A study of the teeth will give a key to the life of the animal, and the teacher should collect a few mammalian skulls as opportunities offer. The pupils should be required to identify them by means of the chart of skulls (p. 194). If some enthusiastic students fond of anatomy should dissect small mammals, the specimens should be killed with chloroform, and the directions for dissection usual in laboratory works on this subject may be followed. There is a brief guide on page 223. The following outline for the study of a live mammal will apply almost as well to the rabbit or the squirrel as to the cat.

**The Cat.** — The house cat (*Felis domestica*) is probably descended from the Nubian cat (*Felis maniculata*, Fig. 333) found in Africa. The wild species is about half as large again as the domestic cat, grayish brown with darker stripes; the tail has dark rings. The lynx, or wild cat of America (*Lynx rufus*), is quite different. Compare the figures (333, 335) and state three obvious differences. To which American species is the house cat closer akin, the lynx (Fig. 335) or the ocelot (Fig. 334)? The domestic cat is found among all nations of the world. What is concluded, as to its nearest relatives, from the fact that the Indians had no cats when America was discovered? It was considered sacred by the ancient Egyptians, and after death its body was embalmed.

The body of the cat is very flexible. It may be divided into five regions, head, neck, trunk, tail, and limbs. Its

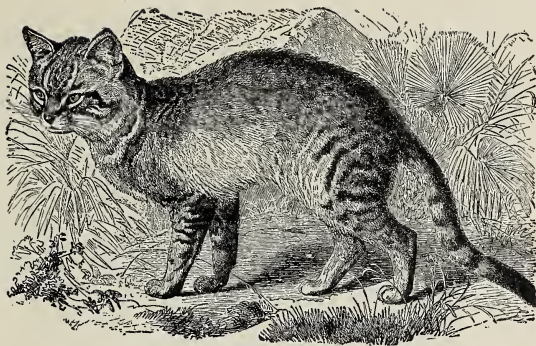


FIG. 333. — WILD CAT OF AFRICA (*Felis maniculata*),  $\times \frac{1}{6}$ .

*eyes* have the same parts as the eyes of other mammals. Which part of its eye is most peculiar? (Fig. 333.) What part is lacking that is present in birds? How are the eyes especially adapted for seeing at night? Does the pupil in the light extend up or down or across the iris? Does it ever become round?

What is the shape and the position of the *ears*? Are they large or small compared with those of most mammals? They are fitted best for catching sound from what direction? What is thus indicated in regard to the cat's habits? (Compare with ears of rabbit.) Touch the *whiskers* of the cat. What result? Was it voluntary or involuntary motion? Are the *nostrils* relatively large or small compared with those of a cow? Of man?

Is the *neck* long or short? Animals that have long fore legs usually have what kind of neck? Those with short legs? Why? How many *toes* on a fore foot? Hind foot? Why is this arrangement better than the reverse? Some mammals are sole walkers (*plantigrade*), some are toe walkers (*digitigrade*). To which kind does the cat



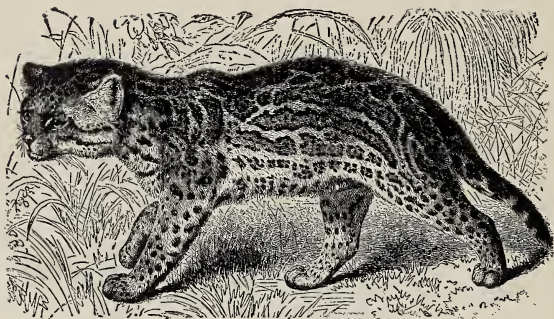


FIG. 334.—OCELOT (*Felis pardalis*), of Texas and Mexico.  $\times \frac{1}{3}$ .

belong? Does it walk on the ends of the toes? Does it walk with all the joints of the toes on the ground? Where is the *heel* of the cat? (Fig. 334.) The *wrist*? To make sure of the location of the wrist, begin above: find the shoulder blade, the upper arm (one or two bones?), the lower arm (one or two bones?), the wrist, the palm, and the fingers (Fig. 337). Is the heel bone prominent or small?

In what direction does the *knee* of the cat point? The heel? The elbow? The wrist? Compare the front and the hind *leg* in length; straightness; heaviness; number and position of toes; sharpness of the *claws*. What makes the *dog's claws* duller than a cat's? What differences in habit go with this? Judging from the toe that has become useless on the fore foot of the cat, which toe is lacking in the hind foot? Is it the cat's thumb or little finger that does not touch the ground? (Fig. 337.) Locate on your own hand the parts corresponding to the pads on the forefoot of a cat. Of what use are soft pads on a cat's foot?

Some animals have short, soft fur and long, coarse over hair. Does the cat have both? Is the cat's fur soft or coarse? Does the fur have a colour near the skin different



from that at the tip? Why is hair better suited as a covering for the cat than feathers would be? Scales? Where are long, stiff bristles found on the cat? Their length suggests that they would be of what use to a cat in going through narrow places? Why is it necessary for a cat to be noiseless in its movements?



FIG. 335.—LYNX (*Lynx rufus*). The "Bob-tailed cat" (North America).

Observe the **movements of the cat.**—Why cannot a cat come down a tall tree head foremost? Did you ever see a cat catch a bird? How does a cat approach its prey? Name a jumping insect that has long hind legs; an amphibian; several mammals (Figs. 362, 374). Does a cat ever trot? Gallop? Does a cat chase its prey? When does the cat move with its heel on the ground? The claws of a cat are withdrawn by means of a tendon (see Fig. 338). Does a cat seize its prey with its mouth or with its feet?

How does a cat make the purring sound? (Do the lips move? The sides?) How does a cat drink? Do a cat

and dog drink exactly the same way? Is the cat's tongue rough or smooth? How is the tongue used in getting the flesh off close to the bone? Can a cat clean a bone entirely of meat?

In what state of development is a newly born kitten? With what does the cat *nourish its young*?

Name ten animals of various kinds whose young are similarly nourished. What is this class of animals called?



FIG. 336. — JAGUAR, of tropical America.

Why does a cat bend its back when it is frightened or angry? Does a cat or a dog eat a greater variety of food? Which refuses to eat an animal found dead? Will either bury food for future use? Which is sometimes troublesome on account of digging holes in the garden? Explain this instinct. Which lived a solitary life when wild? Which had a definite haunt, or home? Why are dogs more sociable than cats? A dog is more devoted to his master. Why? A cat is more devoted to its home, and will return if carried away. Why? Why does a dog turn around before lying down? (Consider its original environment.)

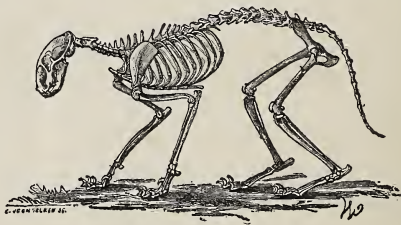


FIG. 337. — SKELETON OF CAT.

**The Skeleton** (Fig. 337). -- Compare the *spinal column* of a cat in form and flexibility with the spinal column of a fish, a snake, and a bird.

The *skull* is joined to the spinal column by two knobs (or *condyles*), which fit into sockets in the first vertebra. Compare the jaws with those of a bird and a reptile. There is a prominent ridge in the temple to which the powerful chewing muscles are attached. There is also a ridge at the back of the head where the muscles which support the head are attached (Fig. 348).

Count the *ribs*. Are there more or fewer than in man? The breastbone is in a number of parts, joined, like the vertebræ, by cartilages. Compare it with a bird's sternum; why the difference? The shoulder girdle, by which the front legs are attached to the trunk, is hardly to be called a girdle, as the collar bones (clavicles) are rudimentary. (They often escape notice during dissection, being hidden by muscles.) The shoulder blades, the other bones of this girdle, are large, but relatively not so broad toward the dorsal edge as human shoulder blades. The clavicles are tiny because they are useless. Why does the cat not need as movable a shoulder as a man? The pelvic, or hip girdle, to which the hind legs are attached, is a rigid girdle, completed above by the spinal column, to which it is immovably joined. Thus the powerful hind legs are joined to the most rigid portion of the trunk.

**Mammals.**—The cat belongs to the *class Mammalia* or mammals. The characteristics of the class are that the young are not hatched from eggs, but *are born alive, and nourished with milk* (hence have lips), and the *skin is covered with hair*. The milk glands are situated ventrally. The position of the class in the animal kingdom was

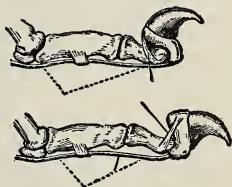


FIG. 338. — CLAW OF CAT  
(1) retracted by ligament, and  
(2) drawn down by muscle  
attached to lower tendon.

shown when the cow was classified (p. 9). Their care for the young, their intelligence, and their ability to survive when in competition with other animals, causes the mammals to be considered the highest class in the animal kingdom.

According to these tests, what class of vertebrates should rank next to mammals? Compare the heart, the lungs, the blood, and the parental devotion of these two highest classes of animals.

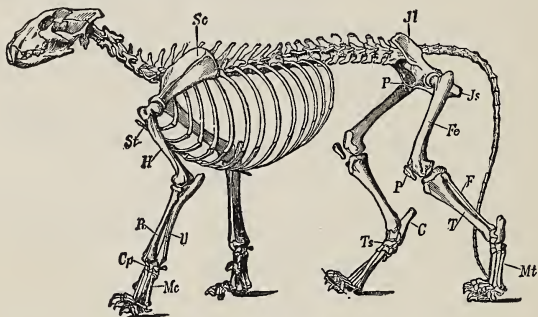


FIG. 339.—SKELETON OF LION (cat family).

The first mammals, which were somewhat like small opossums, appeared millions of years ago, when the world was inhabited by giant reptiles. These reptiles occupied the water, the land, and the air, and their great strength and ferocity would have prevented the mammals from multiplying (for at first they were small and weak), but the mammals carried their young in a pouch until able to care for themselves, while the reptiles laid eggs and left them uncared for. The first mammals used reptilian eggs for food, though they could not contend with the great reptiles. Because birds and mammals are better parents than reptiles, they have conquered the earth, and the rep-

tiles have been forced into subordination, and have become smaller and timid.

**Classification of Mammals.** — Which two have the closest *resemblances* in the following lists: Horse, cow, deer. Why? Cat, cow, bear. Why? Monkey, man, sheep. Why? Rat, monkey, squirrel. Why? Giraffe, leopard, camel. Why? Walrus, cat, cow. Why? Check the five mammals in the following lists that form a group *resembling one another most closely*: Lion, bear, pig, dog, squirrel, cat, camel, tiger, man. State your reasons. Giraffe, leopard, deer, cow, rat, camel, hyena, horse, monkey. State reasons.

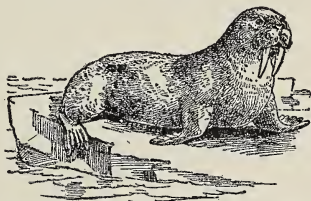


FIG. 340. — WALRUS (*Trichechus rosmarus*).



FIG. 341. — WEASEL, in summer; in Canada in winter it is all white but tip of tail.

**Teeth and Toes** are the basis for subdividing the class mammalia into orders. Although the breathing, the circulation, and the internal organs and processes are similar in all mammals, the external organs vary greatly because of the varying environments of different species. The internal structure enables us to place animals together which are essentially alike; *e.g.* the whale and man are both mammals, since they resemble in breathing, circulation, and multiplication of young. The external organs guide us in separating the class into orders. The teeth vary according to the food



eaten. The feet vary according to use in obtaining food or escaping from enemies. This will explain the difference



FIG. 342.—FOOT OF BEAR  
(Plantigrade).

in the length of legs of lion and horse, and of the forms of the teeth in cat and cow. Make a careful study of the teeth and the limbs as shown in the figures and in all specimens accessible.

Write out the dental formulas as indicated at the top of page 194. The numerals above the line show the number of upper teeth, those below the line show the number of lower teeth, in one half of the jaw. They are designated as follows: *I*, incisors; *C*, canine; *M*, molars. Multiplying by two gives the total number. Which skulls in the chart have the largest canines? Why? The smallest, or none at all? Why? Compare the molars of the cow, the hog, and the dog. Explain their differences. In which skulls are some of the molars lacking? Rudimentary? Why are the teeth that do not touch usually much smaller than those that do?



FIG. 343.—POLAR BEAR (*Ursus maritimus*).



## KEY, OR TABLE, FOR CLASSIFYING MAMMALS

(class *Mammalia*) INTO ORDERS

ORDERS

**A<sub>1</sub> Imperfect Mammals**, young hatched or prematurely bornB<sub>1</sub> Jaws a birdlike beak, egg-laying*Mon'otremes*B<sub>2</sub> Jaws not beaklike, young carried in pouch*Marsu'pials***A<sub>2</sub> Perfect Mammals**, young not hatched, nor prematurely born

B<sub>1</sub> { C Front part of both jaws lack teeth  
 Digits { C<sub>2</sub> Teeth with sharp points for piercing  
 with { shells of insects  
 claws { C<sub>3</sub> Canines very long, molars suited for  
 tearing  
 { C<sub>4</sub> Canines lacking, incisors very large

*Eden'tates**Insect'ivors**Car'nivors**Rodents*

B<sub>2</sub> { C<sup>1</sup> Head large; carnivorous  
 Digits { C<sub>2</sub> Head small; herbivorous  
 not {  
 distinct {

*Ceta'ceans**Sire'neans*

B<sub>3</sub> { C<sup>1</sup> Five toes, nose prolonged into a snout  
 Digits { C<sub>2</sub> Toes odd number, less than five  
 with { C<sub>3</sub> Toes even number, upper front teeth  
 nails { lacking, chew the cud  
 or { C<sub>4</sub> Toes even number, upper front teeth  
 hoofs { present, not cud-chewers  
 { C<sub>5</sub> All limbs having hands  
 { C<sub>6</sub> Two limbs having hands

*Proboscid'eans**E'quines**Ru'minants**Swine**Quad'ruman's**Bi'mans*} *Ungulates*

**Exercise in Classification.**—Copy the following list, and by reference to figures write the name of its order after each mammal:—

Ape (Figs. 405, 406)

Cow (Figs. 344, 386)

Antelope (Fig. 391)

Rabbit (Fig. 345)

Walrus (Fig. 340)

Mole

Dog (Figs. 356, 408)

Monkey

(Figs. 367, 368)

Hog (Figs. 357, 393)

(Figs. 352, 401)

Beaver

Bat (Figs. 347, 370)

Horse

(Figs. 372, 373)

Cat (Figs. 337, 348)

(Figs. 355, 395)

Duckbill (Fig. 359)

Armadillo

Ant-eater

Tapir (Fig. 384)

(Figs. 349, 365)

(Figs. 354, 364)

Dolphin (379, 397)

Use chart of Skulls and Figs. 381, 382, 395-400 in working out this exercise.

Man's dental formula is  $\left( M \frac{5}{5}, C \frac{1}{1}, I \frac{2}{2} \right)^2 = 32$ .

In like manner fill out formulas below:—

Cow .....  $(M - C - I)^2 = 32$

Rabbit .....  $(M - C - I)^2 = 28$

Walrus .....  $(M - C - I)^2 = 34$

Bat .....  $(M - C - I)^2 = 34$

Cat .....  $(M - C - I)^2 = 30$

Armadillo .....  $(M - C - I)^2 = 28$

Horse .....  $(M - C - I)^2 = 40$

Whale .....  $(M - C - I)^2 = 0$

Am. Monkey...  $(M - C - I)^2 = 36$

Sloth .....  $(M - C - I)^2 = 18$

Ant-eater .....  $(M - C - I)^2 = 0$

Dog .....  $(M - C - I)^2 = 42$

Hog .....  $(M - C - I)^2 = 44$

Sheep .....  $(M - C - I)^2 = 32$

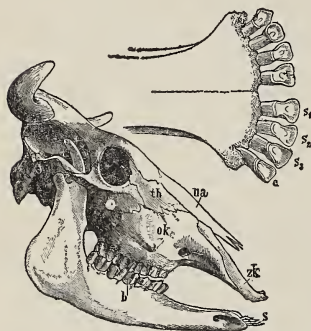


FIG. 344. — Skull and front of lower jaw of Cow.



FIG. 346. — WALRUS (see Fig. 341).



FIG. 347. — BAT.

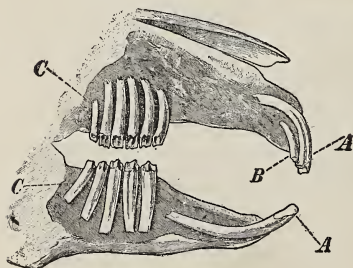


FIG. 345. — RABBIT.  
A, B, incisors; C, molars



FIG. 348. — CAT.



FIG. 349. — ARMADILLO.



FIG. 354. — ANT-EATER (Fig. 364).



FIG. 350. — HORSE  
(front of jaw).

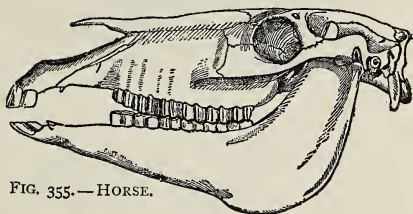


FIG. 355. — HORSE.

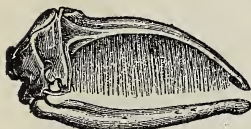


FIG. 351. — GREENLAND  
WHALE.



FIG. 356. — DOG. Upper (A) and lower (B) jaw.



FIG. 352. — AMERICAN MONKEY.

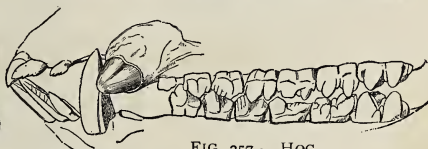


FIG. 357. — HOG.



FIG. 358. — SHEEP.



FIG. 353. — SLOTH (Fig. 363).

The lowest order of mammals contains only two species, the duckbill and the porcupine ant-eater, both living in



FIG. 359. — DUCKBILL (*Ornithorhynchus paradoxus*).

the Australian region. Do you judge that the *duckbill* of Tasmania (Fig. 359) lives chiefly in water or on land?

Why? Is it probably active or slow in movement? It dabbles in mud and slime for worms and mussels, etc. How is it fitted for doing this? Which feet are markedly webbed? How far does the web extend? The web can be folded back when not in use. It lays two eggs in a nest of grass at the end of a burrow. Trace resemblances and differences between this animal and birds.

The *porcupine ant-eater* has numerous quill-like spines (Fig. 360) interspersed with its hairs. (Use?) Describe its claws. It has a long prehensile



FIG. 360. — SPINY ANT-EATER (*Echidna aculeata*). View of under surface to show pouch. (After Haacke.)

tongue. It rolls into a ball when attacked. Compare its jaws with a bird's bill. It lays one egg, which is carried

in a fold of the skin until hatched. Since it is pouched it could be classed with the pouched mammals (next order), but it is egg-laying. Suppose the two animals in this order did not nourish their young with milk after hatching, would they most resemble mammals, birds, or reptiles?

Write the name of this *order*. \_\_\_\_\_ (See Table, p. 193.) *Why* do you place them in this order (\_\_\_\_\_)? See p. 193.) The name of the order comes from two Greek



FIG. 361. — OPOSSUM (*Didelphys Virginianus*).

words meaning “one opening,” because the ducts from the bladder and egg glands unite with the large intestine and form a cloaca. What other classes of vertebrates are similar in this?

**Pouched Mammals.** — These animals, like the last, are numerous in the Australian region, but are also found in South America, thus indicating that a bridge of land once connected the two regions. The *opossum* is the only species which has penetrated to North America (Fig. 361). Are its jaws slender or short? What kinship is thus suggested? As shown by its grinning, its lips are not well de-



veloped. Does this mean a low or a well-developed mammal? Where does it have a thumb? (Fig. 361.) Does the thumb have a nail? Is the tail hairy or bare? Why? Do you think it prefers the ground or the trees? State two reasons for your answer. It hides in a cave or bank or hollow tree all day, and seeks food at night. Can it run fast on the ground? It feigns death when captured,



FIG. 362. — GIANT KANGAROO.

and watches for a chance for stealthy escape.

The *kangaroo* (Fig. 362), like the opossum, gives birth to imperfectly developed young. (Kinship with what classes is thus indicated?) After birth, the young (about three fourths of an inch long)

are carried in a ventral pouch and suckled for seven or eight months. They begin to reach down and nibble grass before leaving the pouch. Compare fore legs with hind legs, front half of body with hind half. Describe tail. What is it used for when kangaroo is at rest? In jumping, would it be useful for propelling and also for balancing the body? Describe hind and fore feet. *Order—Why?—* See key, page 193.

**Imperfectly Toothed Mammals.**—These animals live chiefly in South America (sloth, armadillo, giant ant-eater) and Africa (pangolin). The sloth (Fig. 363) eats leaves. Its movements are remarkably slow, and a vegetable growth



resembling moss often gives its hair a green colour. (What advantage?) How many toes has it? How are its nails suited to its manner of living? Does it save exertion by hanging from the branches of trees instead of walking upon them?

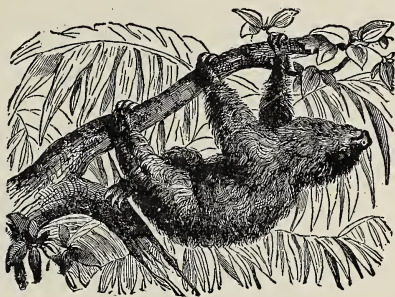


FIG. 363. — SLOTH of South America.

Judging from the figures (363, 364, 365), are the members of this order better suited for at-

tack, active resistance, passive resistance, or concealment

when contending with other animals? The ant-eater's claws (Fig. 364) on the fore feet seem to be a hindrance in walking; for what are they useful? Why are its jaws so slender? What is probably the use of the enormous bushy tail? The



FIG. 364. — GIANT ANT-EATER of South America.  
(See Fig. 354.) Find evidences that the edentates are a degenerate order. Describe another ant-eater (Fig. 360).

nine-banded armadillo (Fig. 365) lives in Mexico and Texas. It is omnivorous. To escape its enemies, it burrows into

the ground with surprising rapidity. If unable to escape when pursued, its hard, stout tail and head are turned

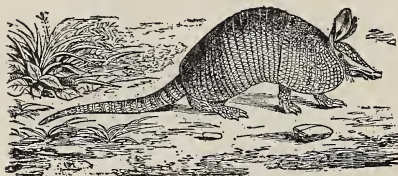


FIG. 365.—NINE-BANDED ARMADILLO of Texas and Mexico. (*Dasypus novemcinctus*.) It is increasing in numbers; it is very useful, as it digs up and destroys insects. (See Fig. 347.)

under to protect the lower side of the body where there are no scales. The three-banded species (Fig. 366) lives in Argentina. Compare the ears and tail of the two species; give reasons for differences.

Why are the eyes so small? The claws so large? Order \_\_\_\_\_. Why? \_\_\_\_\_.

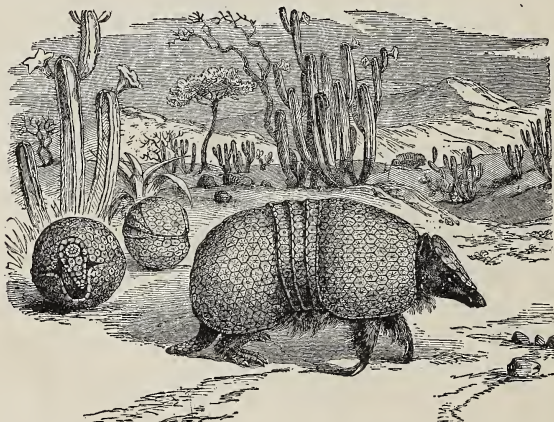


FIG. 366.—THREE-BANDED ARMADILLO (*Tolypeutes tricinctus*).

**Insect Eaters.** — The soft interior and crusty covering of insects makes it unnecessary for animals that prey upon them to have flat-topped teeth for grinding them to

powder, or long cusps for tearing them to pieces. The teeth of insect eaters, even the molars (Fig. 368), have many sharp tubercles, or points, for holding insects and piercing the crusty outer skeleton and reducing it to bits. As most insects dig in the ground or fly in the air, we are not surprised to learn that some insect-eating mam-

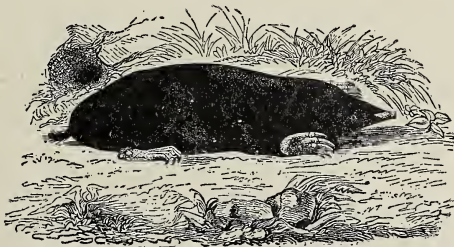


FIG. 367. — THE MOLE.

mals (the bats) fly and others (the moles) burrow. Are the members of this order friends or competitors of man?

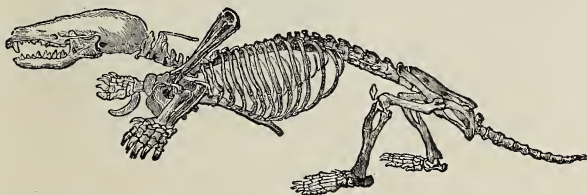


FIG. 368. — SKELETON OF MOLE. (Shoulder blade is turned upward.,

Why does *the mole* have very small eyes? Small ears? Compare the shape of the body of a mole and a rat. What difference? Why? Compare the front and the hind legs of a mole. Why are the hind legs so small and weak? Bearing in mind that the body must be arranged for digging and using narrow tunnels, study the skeleton

(Fig. 368) in respect to the following: Bones of arm (length and shape), fingers, claws, shoulder bones, breast-bone (why with ridge like a bird?), vertebræ (why are the first two so large?), skull (shape). There are no eye sockets, but there is a snout gristle; for the long, sensitive snout must serve in place of the small and almost useless eyes hidden deep in the fur. Is the fur sleek or rough? Why? Close or thin? It serves to keep the mole clean. The muscles of neck, breast, and shoulders are very strong. Why? The mole eats earthworms as well as insects. It injures plants by breaking and drying out their roots. Experiments show that the Western mole will eat moist grain, though it prefers insects. If a mole is caught, repeat the experiment, making a careful record of the food placed within its reach.

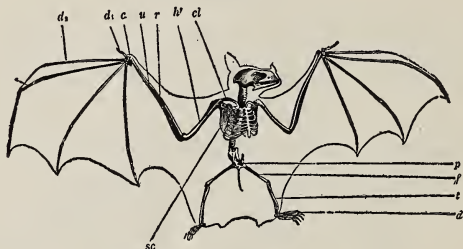


FIG. 369. — SKELETON OF BAT.

As with the mole, the skeletal adaptations of *the bat* are most remarkable in the hand. How many fingers? (Fig. 369.) How many nails on the hand? Use of nail when at rest? When creeping? (Fig. 369.) Instead of feathers, the flying organs are made of a pair of extended folds of the skin supported by elongated bones, which form a framework like the ribs of an umbrella or a fan. How many digits are prolonged? Does





FIG. 370. — VAMPIRE (*Phyllostoma spectrum*) of South America.  $\times \frac{1}{2}$ .

the fold of the skin extend to the hind legs? The tail? Are the finger bones or the palm bones more prolonged to form the wing skeleton?

The skin of the wing is rich in blood-vessels and nerves, and serves, by its sensitiveness to the slightest current of air, to guide the bat in the thickest darkness. Would you judge that the bat has sharp sight? Acute hearing?

The moles do not *hibernate*; the bats do. Give the reason for the difference. If bats are aroused out of a trance-like condition in winter, they may die of starvation. Why? The mother bat carries the young about with her, since, unlike birds, she has no nest. How are the young nourished? *Order* \_\_\_\_\_. *Why?* \_\_\_\_\_. (Key, p. 193.)

**The Gnawing Mammals.**—These animals form the most numerous order of mammals. They *lack canine* teeth. Inference? The incisors are four in number in all species

except the rabbits, which have six (see Fig. 345). They are readily recognized by their *large incisors*. These teeth grow throughout life, and if they are not constantly worn



FIG. 371. — POUCHED GOPHER (*Geomys bursarius*)  $\times \frac{1}{4}$ , a large, burrowing field rat, with cheek pouches for carrying grain.

away by gnawing upon hard food, they become inconveniently long, and may prevent closing of the mouth and cause starvation. The hard enamel is all on the front surface, the dentine in the rear being softer; hence the incisors sharpen themselves by use to a chisel-like edge.

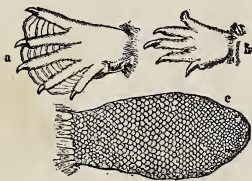


FIG. 372. — Hind foot *a*, fore foot *b*, tail *c*, of BEAVER.



FIG. 373. — BEAVER.

The molars are set close together and have their upper surfaces level with each other. The ridges on them run crosswise so as to form a continuous filelike surface for



reducing the food still finer after it has been gnawed off (Fig. 345). The lower jaw fits into grooves in place of sockets. This allows the jaw to work back and forth instead of sidewise. The rabbits and some squirrels have a hare lip; *i.e.* the upper lip is split. What advantage is this in eating? In England the species that burrow are called rabbits; those that do not are called hares.

Name six enemies of rabbits. Why does a rabbit usually sit motionless unless approached very close? Do you usually see one before it dashes off? A rabbit has from three to five litters of from three to six young each year. Squirrels have fewer and smaller litters. Why must the rabbit multiply more rapidly than the squirrel in order to survive? English rabbits have increased in Australia until they are a plague. Sheep raising is interfered with by the loss of grass.



FIG. 374.—POSITION OF LIMBS IN RABBIT.

The Australians now ship them to England in cold storage for food. Rabbits and most rodents lead a watchful, timid, and alert life. An exception is the porcupine, which, because of the defence of its barbed quills, is dull and sluggish.

The common rodents are:—

squirrels	beavers	pouched gopher	ground-hog
rabbits	muskrats	prairie dog	field-mouse
rats	porcupines	prairie squirrel	
mice	guinea pig	chipmunk	

Which of the above rodents are commercially important? Which are injurious to an important degree? Which have long tails? Why? Short tails? Why? Long ears? Why?

Short ears? Why? Which are aquatic? Which dig or burrow? Which are largely nocturnal in habits? Which are arboreal? Which are protected by coloration? Which escape by running? By seeking holes?

**Economic Importance.** — Rabbits and squirrels destroy the eggs and young of birds. Are rabbits useful? Do they destroy useful food? The use of beaver and muskrat skins as furs will probably soon lead to their extinction. Millions of rabbits' skins are used annually, the hair being made into



FIG. 375. — FLYING SQUIRREL (*Pteromys volucella*).  $\times \frac{1}{4}$ .

felt hats. There are also millions of squirrel skins used in the fur trade. The hairs of the tail are made into fine paint brushes. The skins of common rats are used for the thumbs of kid gloves. *Order* \_\_\_\_\_. *Why?* \_\_\_\_\_.

**Elephants.** — Elephants, strange to say, have several noteworthy resemblances to rodents. Like them, elephants have no canine teeth; their molar teeth are few, and marked by transverse ridges and the incisors present are prominently developed (Figs. 376, 377). Instead of four incisors, however, they have only two, the enormous tusks, for there are no incisors in the lower jaw. Elephants and rodents

both subsist upon plant food. Both have peaceful dispositions, but one order has found safety and ability to survive by attaining enormous size and strength; the other (*e.g.* rats, squirrels) has found safety in small size. Explain.

Suppose you were to observe an elephant for the first time, without knowing any of its habits. How would you know that it does not eat meat? That it does eat plant food? That it can defend it-

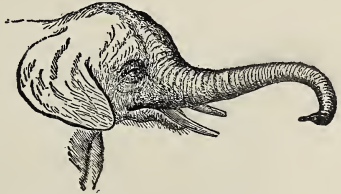


FIG. 376.—HEAD OF AFRICAN ELEPHANT.

self? Why would you make the mistake of thinking that it is very clumsy and stupid? Why is its skin naked? Thick? Why must its legs be so straight? Why must it have either a very long neck or a substitute for one? (Fig. 376.) Are the eyes large or small? The ears? The brain cavity? What anatomical feature correlates with the long proboscis? Is the proboscis a new organ not found in other animals, or is it a specialization of one or more old ones? Reasons? What senses are especially active in the proboscis? How is it used in drinking? In



FIG. 377.—MOLAR TOOTH OF AFRICAN ELEPHANT.

grasping? What evidence that it is a development of the nose? The upper lip?

The tusks are of use in uprooting trees for their foliage and in digging soft roots for food. Can the elephant graze? Why, or why not? There is a finger-like projection on the end of the snout which is useful in delicate manipulations. The feet have pads to prevent jarring; the nails are short and hardly touch the ground. *Order* \_\_\_\_\_. *Why?* \_\_\_\_\_. Key, page 193.

**Whales, Porpoises, Dolphins.** — As the absurd mistake is sometimes made of confusing *whales* with fish, the pupil may compare them in the following respects: eggs, nourishment of young, fins, skin, eyes, size, breathing, temperature, skeleton (Figs. 209, 379, and 397).

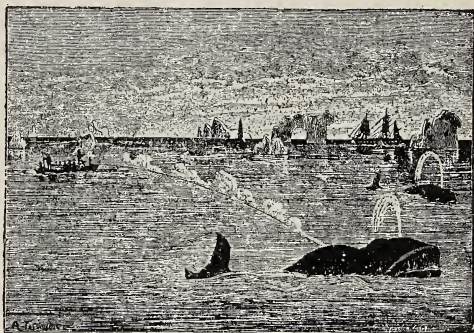


FIG. 378. — HARPOONING GREENLAND WHALE  
(see Fig. 351).

*Porpoises and dolphins*, which are smaller species of whales, live near the shore and eat fish. Explain the expression “blow like a porpoise.” They do not exceed five or eight feet in length, while the deep-sea whales are from thirty to seventy-five feet in length, being by far the largest animals in the world. The size of the elephant is limited by the weight that the bones and muscles support and move. The whale’s size is not so limited.

The *whale* bears one young (rarely twins) at a time. The mother carefully attends the young for a long time. The *blubber*, or thick layer of fat beneath the skin, serves to retain heat and to keep the body up to the usual temperature of mammals in spite of the cold water. It also serves, along with the *immense lungs*, to give lightness to the body.

Why does a whale need large lungs? The *tail of a whale*

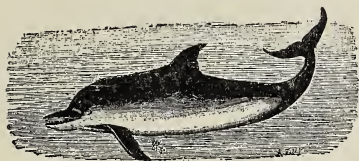


FIG. 379. — DOLPHIN.

is horizontal instead of vertical, that it may steer upward rapidly from the depths when needing to breathe. The *teeth* of some whales do not cut the

gum, but are reabsorbed and are replaced by horny plates of "whalebone," which act as strainers. Give evidence, from the flippers, lungs, and other organs, that the whale is descended from a land mammal (Fig. 397). Compare the whale with a typical land mammal, as the dog, and enumerate the specializations of the whale for living in water. What change took place in the general form of the body? It is believed that on account of scarcity of food the land ancestors of the whale, hundreds of thousands of years ago, took to living upon fish, etc., and, gradually becoming swimmers and divers, lost the power of locomotion on land. *Order* \_\_\_\_\_. *Why?* \_\_\_\_\_.

Elephants are rapidly becoming extinct because of the value of their ivory tusks. Whales also furnish valuable products, but they will probably exist much longer. *Why?*



FIG. 380. — MANATEE, or sea cow; it lives near the shore and eats seaweed. (Florida to Brazil.)

The **manatees and dugongs** (sea cows) are a closely related order living upon water plants, and hence living close to shore and in the mouths of rivers. *Order* \_\_\_\_\_. *Why?* \_\_\_\_\_.



**Hoofed Mammals.** — All the animals in this order walk on the tips of their toes, which have been adapted to this use by the claws having developed into *hoofs*. The order is subdivided into the *odd-toed* (such as the horse with one toe and the rhinoceros with three) and the *even-toed* (as the ox with two toes and the pig with four). All the even-toed forms except the pig and hippopotamus chew the cud and are given the name of *ruminants*.

**Horse and Man Compared.** — To which finger and toe on man's hand and foot does a horse's foot correspond?

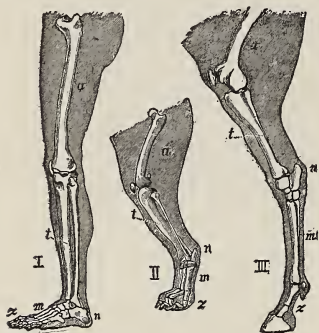


FIG. 381. — Left leg of man, left hind leg of dog and horse; homologous parts lettered alike.

(Figs. 381, 383, 399.)

Has the horse kneecaps?

Is its heel bone large or small?

Is the fetlock on toe, instep, or ankle?

Does the part of a horse's hind leg that is most elongated correspond to the thigh, calf, or foot in man?

On the fore leg, is the elongated part the upper arm, forearm, or hand?

(Figs. 395, 399.)

Does the most elongated part of the fore foot correspond to the finger, the palm, or the wrist?

(Fig. 382.)

On the hind foot is it toe, instep, or ankle?

Is the fore fetlock on the finger, the palm, or the wrist?

(Figs. 382, 385, 399.)

Is the hock at the toe, the instep, the heel, or the knee?

Does the most elongated part of the fore foot correspond to the finger, the palm, or the wrist?

(Fig. 382.)

On the hind foot is it toe, instep, or ankle?

Is the fore fetlock on the finger, the palm, or the wrist?

(Figs. 382, 385, 399.)

Is the hock at the toe, the instep, the heel, or the knee?

**Specializations of the Mammals.** — The early mammals, of which the present marsupials are believed to be typical, had five toes provided with claws. They were not very rapid in motion nor dangerous in fight, and probably ate both animal and vegetable food.



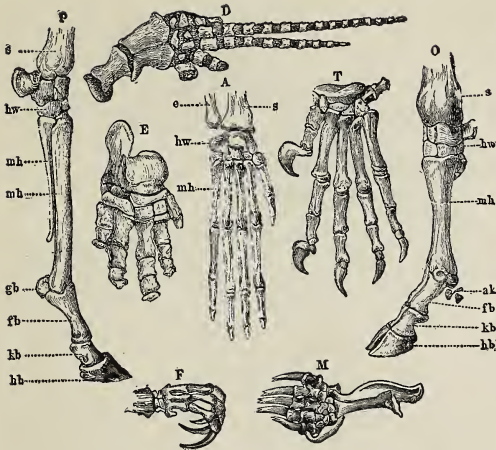


FIG. 382. — SKELETONS OF FEET OF MAMMALS.

*P*, horse; *D*, dolphin; *E*, elephant; *A*, monkey; *T*, tiger; *O*, aurochs;  
*F*, sloth; *M*, mole.

Question: Explain how each is adapted to its specialized function.

According to the usual rule, they tended to increase faster than the food supply, and there were continual contests for food. Those whose claws and teeth were sharper drove the others from the food, or preyed upon them. Thus the specialization into the bold flesh-eating beasts of prey and the timid vegetable feeders began. Which of the flesh eaters has already been studied at length? The insectivora escaped their enemies and found food by learning to burrow or fly. The rodents accomplished the same result either by acquiring great agility in climbing, or by living in holes, or by running. The proboscidiens acquired enormous size and strength. The hoofed animals found safety in flight.

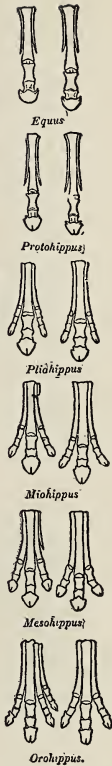


FIG. 383. — Feet of the ancestors of the horse.

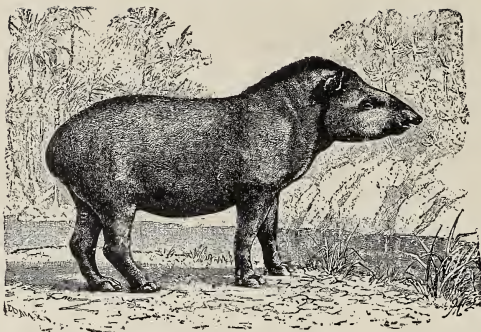


FIG. 384. — TAPIR OF SOUTH AMERICA (*Tapirus americanus*).  $\times \frac{1}{2}$ .

Questions: How does it resemble an elephant? (Fig. 376.) A horse? (p. 210.)

Ungulates, as the horse, need no other protection than their great speed, which is due to lengthening the bones of

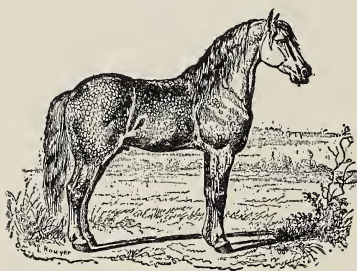


FIG. 385. — HORSE, descended from a small wild species still found in Western Asia.

the legs and rising upon the very tip of the largest toe, which, to support the weight, developed an enormous toe-nail called a hoof. The cattle, not having developed such speed as the horse, usually have horns for defence. If a calf

or cow bellows with distress, all the cattle in the neighbourhood rush to the rescue. This unselfish instinct to help others was an aid to the survival of wild cattle living in regions infested with beasts of prey. Which of Æsop's fables is based upon this instinct? The habit of rapid grazing and the correlated habit of chewing the cud were also of great value, as it enabled cattle to obtain grass hur-

riedly and to retire to a safe place to chew it. Rudiments of the upper incisors are present in the jaw of the calf, showing the descent from animals which had a complete set of teeth. The rudiments are absorbed, and the upper jaw of the cow lacks incisors entirely, as they would be useless because of the cow's habit of seizing the grass with her

rough tongue and cutting it with the lower incisors as the head is jerked forward. This is a more rapid way of eating than by biting. Which leaves the grass shorter

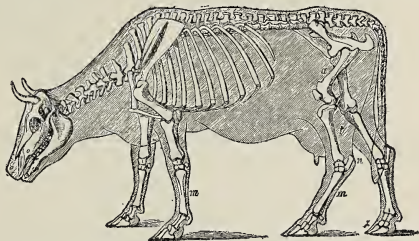


FIG. 386.—SKELETON OF COW. Compare with horse (Fig. 395) as to legs, toes, tail, mane, dewlap, ears, body.

after grazing, a cow or a horse? Why? Grass is very slow of digestion, and the ungulates have an alimentary canal twenty to thirty times the length of the body. Thorough chewing is necessary for such coarse food, and the ungulates which chew the cud (ruminants) are able, by leisurely and thorough chewing, to make the best use of the woody fibre (cellulose) which is the chief substance in their food.

**Ruminants** have four divisions to the stomach. Their food is first swallowed into the roomy *paunch* in which, as in the crop of a bird, the bulky food is temporarily stored. It is not digested at all in the paunch, but after being moistened, portions of it pass successively into the *honeycomb*, which forms it into balls to be belched up and ground by the large molars as the animal lies with eyes half closed under the shade of a tree. It is then swal-

lowed a second time and is acted upon in the third division (or *manyplies*) and the fourth division (or *reed*). Next

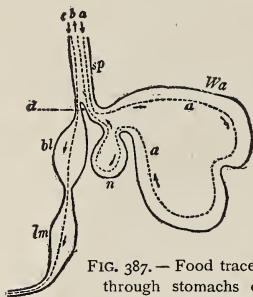


FIG. 387. — Food traced through stomachs of cow. (Follow arrows.)

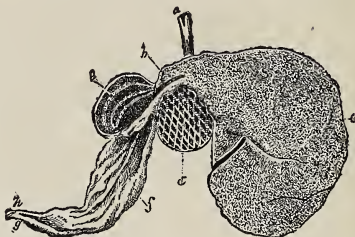


FIG. 388. — Section of cow's stomachs. Identify each. (See text.)

it passes into the intestine. Why is the paunch the largest compartment? In the figure do you recognize the paunch by its size? The honeycomb by its lining? Why is it round? The last two of the four divisions may be known by their direct connection with the intestine.

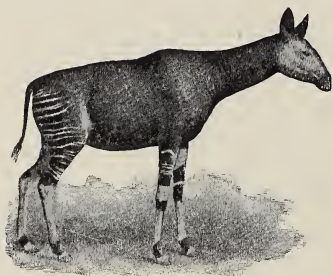


FIG. 389. — OKAPI. This will probably prove to be the last large mammal to be discovered by civilized man. It was found in the forests of the Kongo in 1900.

**Questions:** It shows affinities (find them) with giraffe, deer, and zebra. It is a ruminant ungulate (explain meaning — see text).

ignorant people make the absurd mistake of calling the ball of hair the cud. This ball accumulates in the paunch

The true *gastric juice* is secreted only in the fourth stomach. Since the cud or unchewed food is belched up in balls from the round "honeycomb," and since a ball of hair is sometimes found in the stomach of ruminants, some

because of the friendly custom cows have of combing each other's hair with their rough tongues, the hair sometimes

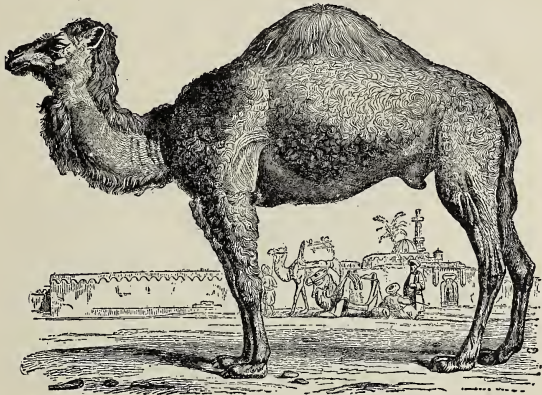


FIG. 390. — AFRICAN CAMEL (*Camelus dromedarius*).

being swallowed. Explain the saying that if a cow stops chewing the cud she will die.

Does a cow's lower jaw move sidewise or back and forth? Do the ridges on the molars run sidewise or lengthwise? Is a cow's horn hollow? Does it have a bony core? (Fig. 344.)

The permanent hollow horns of the cow and the solid deciduous horns of the deer are typical of the two kinds of horns possessed by ruminants. The prong-horned antelope (Fig. 391) of

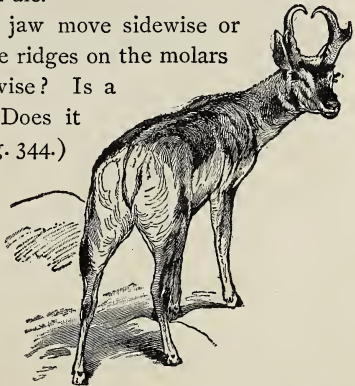


FIG. 391. — PRONG-HORNED ANTELOPE (*Antilocarpa Americana*).



the United States, however, is an intermediate form, as its horns are hollow, but are shed each year. The hollow horns are a modification of hair. Do solid or hollow horns branch? Which are possessed by both sexes? Which are pointed? Which are better suited for fighting? Why would the deer have less need to fight than the cattle? Deer are polygamous, and the males use their



FIG. 392. — ROCKY MOUNTAIN SHEEP (*Ovis montana*).  $\times \frac{1}{24}$ .

horns mostly for fighting one another. The sharp hoofs of deer are also dangerous weapons. The white-tail deer (probably the same species as the Virginian red deer) is the most widely distributed of the American deer. It keeps to the lowlands, while the black-tailed deer prefers a hilly country. The moose, like the deer, browses on twigs and leaves. The elk, like cattle, eats grass.

The native sheep of America is the big horn, or Rocky Mountain sheep (Fig. 392). The belief is false that they



alight upon their horns when jumping down precipices. They post sentinels and are very wary. There is also a native goat, a white species, living high on the Rocky Mountains near the snow. They are rather stupid animals. The bison once roamed in herds of countless thousands, but, with the exception of a few protected in parks, it is now extinct. Its shaggy hide was useful to man in winter, so it has been well-nigh destroyed. For gain man is led to exterminate elephants, seals, rodents, armadillos, whales, birds, deer, mussels, lobsters; forests, etc.

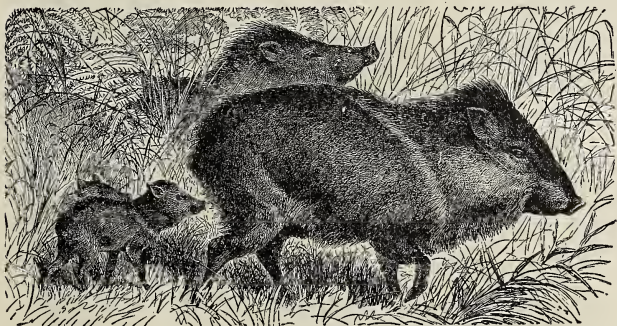


FIG. 393. — PECCARY (*Dicotyles torquatus*) of Texas and Mexico.  $\times \frac{1}{2}$ .

Our only native hog is the peccary, found in Texas (Fig. 393). In contrast with the heavy domestic hog, it is slender and active. It is fearless, and its great tusks are dangerous weapons. The swine are the only ungulates that are not strictly vegetable feeders. The habit of fattening in summer was useful to wild hogs, since snow hid most of their food in winter. The habit has been preserved under domestication. Are the small toes of the hog useless? Are the "dew claws" of cattle useless? Will they probably become larger or smaller? *Order?*

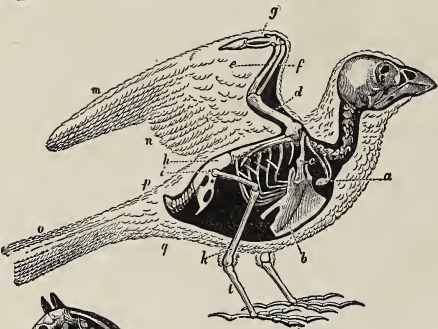


FIG. 394. — BIRD.

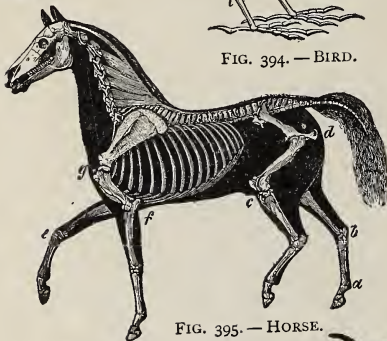


FIG. 395. — HORSE.



FIG. 396. — OX.

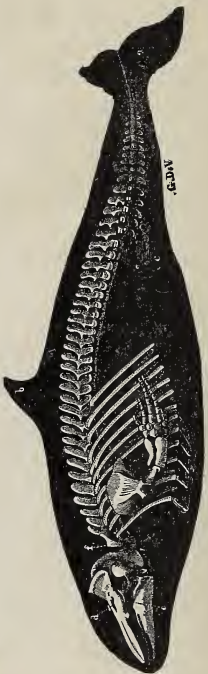
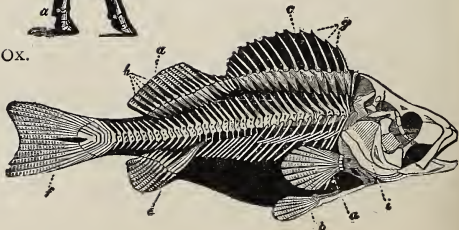


FIG. 397. — DOLPHIN.

FIG. 398. — FISH.



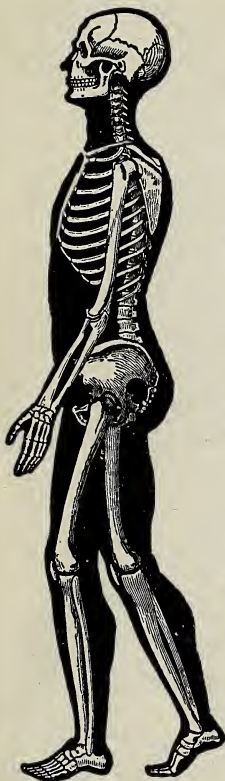


FIG. 399. — MAN.

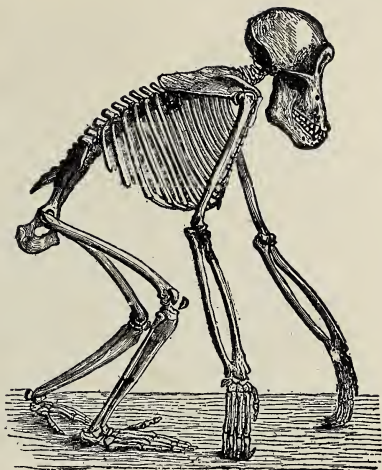


FIG. 400. — CHIMPANZEE. (See Fig. 406.)

**Illustrated Study of Vertebrate Skeletons:**  
Taking man's skeleton as complete, which of these seven skeletons is most incomplete?

Regarding the fish skeleton as the original vertebrate skeleton, how has it been modified for (1) walking, (2) walking on two legs, (3) flying?

Which skeleton is probably a degenerate reversion to original type? (p. 209.)

How is the horse specialized for speed?

Do all have tail vertebrae, or vertebrae beyond the hip bones? Does each have shoulder blades?

Compare (1) fore limbs, (2) hind limbs, (3) jaws of the seven skeletons. Which has relatively the shortest jaws? Why? What seems to be the typical number of ribs? limbs? digits?

Does flipper of a dolphin have same bones as arm of a man?

How many thumbs has a chimpanzee? Which is more specialized, the foot of a man or that of a chimpanzee? Is the foot of a man or that of a chimpanzee better suited for supporting weight? How does its construction fit it for this?

Which has a better hand, a man or a chimpanzee? What is the difference in their arms? Does difference in structure correspond to difference in use?

Which of the seven skeletons bears the most complex breastbone?

Which skeleton bears no neck (or cervical) vertebrae? Which bears only one?

Are all the classes of vertebrates represented in this chart? (p. 125.)



FIG. 401. — SACRED MONKEY OF INDIA (*Semnopithecus entellus*).  $\times \frac{1}{12}$ .

### Monkeys, Apes, and Man.—

Study the figures (399, 400); compare apes and man and explain each of the differences in the following list: (1) feet, three differences; (2) arms; (3) brain case; (4) jaws; (5) canine teeth; (6) backbone; (7) distance between the eyes.

A *hand*, unlike a foot, has one of the digits, called a thumb, placed opposite the other four digits that it may be used in grasping. Two-handed man and four-handed apes and monkeys are usually placed in one order, the *Primates*, or



FIG. 402. — LEMUR (*Lemur Monogoz*).  $\times \frac{1}{10}$ . Which digit bears a claw?



in two orders (see table, page 193). The lowest members of this order are the *lemurs* of the old world. Because of



FIG. 403. — BROAD-NOSED MONKEY.  $\times \frac{1}{10}$ . America.



FIG. 404. — NARROW-NOSED MONKEY.  $\times \frac{1}{15}$ . Old World.

their hands and feet being true grasping organs, they are placed among the primates, notwithstanding the long muzzle and expressionless, foxlike face. (Fig. 402.) Next in order are the *tailed monkeys*, while the *tailless apes* are the highest next to man.

The *primates of the New World* are all monkeys with long tails and broad noses. They are found from Paraguay to Mexico. The *monkeys and apes of the Old World* have a *thin partition* between the nostrils, and are thus distinguished from the



FIG. 405. — GORILLA. (Size of a man.)

monkeys of the New World, which have a *thicker partition* and have a broader nose. (Figs. 403, 404.) The monkeys of America all have *six molar teeth* in each half jaw (Fig. 352); the monkeys and apes of the Old World have thirty-two teeth, which agree both in number and arrangement with those of man.

Which of the primates figured in this book appear to have the arm longer than the leg? Which have the eyes directed forward instead of sideways, as with cats or dogs?



FIG. 406. — CHIMPANZEE.

Nearly all the primates are *forest dwellers*, and inhabit warm countries, where the boughs of trees are never covered with ice or snow. Their *ability in climbing* serves greatly to protect them from beasts of prey. Many apes and monkeys are able to assume the upright position in walking, but they touch the ground with their knuckles

every few steps to aid in preserving the balance.

The *Simians* are the highest family of primates below man, and include the gorilla, chimpanzee, orang, and gibbon. Some of the simians weave together branches in the treetops to form a rude nest, and all are very affectionate and devoted to their young. How are apes most readily distinguished from monkeys? (Figs. 401, 406.)







St. Bernard  
Eskimo  
Poodle  
Dachshund

German mastiff  
English bloodhound

Pointer  
Bulldog  
Greyhound

Newfoundland  
Shepherd  
Spitz

FIG. 408. — ARTIFICIAL SELECTION. Its effects in causing varieties in one species. Which of the dogs is specialized for speed? Driving cattle? Stopping cattle? Trailing by scent? Finding game? Drawing vehicles? Going into holes? House pet? Cold weather? In Mexico there is a hairless dog specialized for hot climates. The widely differing environments under various forms of domestication cause "sports" which breeders are quick to take advantage of when wishing to develop new varieties. Professor De Vries by cultivating American evening primroses in Europe has shown that a sudden change of environment may cause not only varieties but new species to arise.

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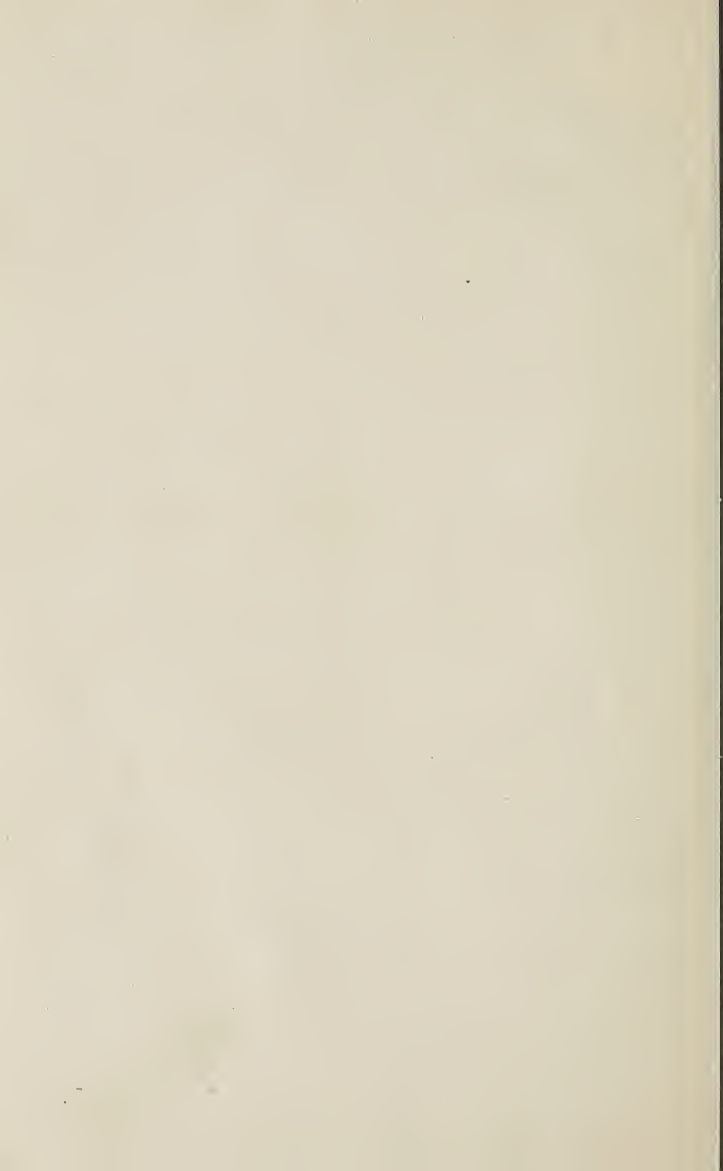
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